HOW AN AEROPLANE IS BUILT

STEPNEY BLAKENEY

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BY

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With an Introduction
by
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HOW AN AEROPLANE IS BUILT

INTRODUCTORY.

By C. G. Grey, Editor of *The Aeroplane*.

This little book, which in its original form appeared as a series of articles in *The Aeroplane*, was written by Mr. Stepney Blakeney at my request, as the result of various entertaining conversations on methods of aeroplane construction. Mr. Blakeney showed such an intimate knowledge of detail work, as well as of workshop lay-out and organisation, that it appeared the right thing to use some of that knowledge for the benefit of the uninitiated.

The book does not profess to be a learned dissertation on factory methods, nor a series of hints and tips on aeroplane construction. It is intended to show in the simplest possible language the way in which a smallish firm, suddenly turned on to produce aeroplanes of an ordinary standard type, might set about the job with reasonable prospects of success.

FOR THE FACTORY WORKER.

In these days there are hundreds of thousands of men and women engaged in making aeroplane parts. Very few of them know whereabouts in an aeroplane the part on which they are working is intended to go, or what it is intended to do when it gets there. Yet many of them would like to know, and would take a keener interest in their work if they understood the why and wherefor thereof. This book will give such intelligent people a fair understanding of the reason for their work and of its importance in the complete aeroplane.

FOR THE DRAUGHTSMAN.

In drawing offices, also, there are many hundreds of fairly well educated men and women, who, though they may be excellent hands at drawing and tracing, have no opportunity of going into the workshops and seeing how the work is done to their drawings, or of seeing what the finished component part looks like before it is put into its place in the machine. Many of them, indeed, are so new to aeroplane work that they could not even locate in a General Arrangement Drawing the precise place where the component part which they have been drawing is intended to fit. They merely work to instructions, without intelligent appreciation of the reasons for

those instructions. Such people, also, will be able to acquire from Mr. Blakeney's description an all-round idea of how the parts of an aeroplane are made, and how they come together to form a complete machine, and it is hoped that this knowledge will help them to find their work more interesting.

FOR THE MERELY INTERESTED.

Over and above the people in aircraft factories there are many thousands of others who are keenly interested in aeroplanes, and who, having a natural liking for things mechanical, are anxious to know by what general methods so much timber and metal is turned into a modern flying machine. These seekers after information will find in this book a simple and easily understandable account of the whole process of manufacture, from the rough plank and the metal sheet to the complete aeroplane ready to make its trial flight.

FOR THE SCHOOLBOY.

One believes, also, that in these days when every youngster at school desires to become an aviator, just as in my young days we aspired to be engine-drivers—motor-cars and aeroplanes being then undiscovered—Mr. Blakeney's simple descriptions of the various workshop processes which go to make an aeroplane will

be highly appreciated by school-boys of the age at which they begin to study the motoring and flying papers.

A GENERAL IDEA.

It must not be thought that Mr. Blakeney's imaginary workshop represents the last word in the development of aircraft factory development. It is, as he points out, a small shop employing a hundred hands or so, and he has laid down its organisation so that it may be capable of expansion to any extent desired. It stands, in fact, in the safe middle position between the old aerodrome shed, in which we used to build our aeroplanes some seven or eight years ago, and the kind of aeronautical sausage factory which will produce the Aerial Fords of the future. Therefore the digestion of the book may be regarded as an easily comprehensible undertaking for any intelligent person who is keen on aeroplanes, and who wants to learn in a general way how they are produced.

THE AUTHOR'S QUALIFICATIONS.

As to Mr. Blakeney's qualifications to write on the subject of aircraft workshop, I should like to point out that for nearly 20 years before the war he was a railway engineer. He served his time in the locomotive shops, which is the best training any engineer can have. Loco

engineers are like the British workman's opinion of beer: "There's no bad beer, but some kinds are better than others." Likewise there are no bad loco engineers, but some are better than others.

After doing loco work in the shops Mr. Blakeney went right through the railway business, driving, plate-laying, ballasting, making cuttings and embankments, building stations, and all the rest of it, so that he is a constructional engineer as well as a workshop manager.

PRACTICAL DEMONSTRATION.

Also I can vouch for the fact that he is himself a first-class machine-hand and fitter, who can take off his coat and show any man in the shop how his job ought to be done. I have known him, when a man has grumbled over a piecework price, hand the man his watch to check the time on the job, and then set about it to such a tune that he showed the man on the man's own timing that he was being paid just twice as much as the job was worth, if only he would take the trouble to do the job the right way.

THE TEACHING OF EXPERIENCE.

Early in the war Mr. Blakeney left the railway and went to a well-known aircraft factory, where he laid down the machine tools in a new machine-shop; designed,

bought the material for, and superintended the erection of a whole new section of the works; reorganised the whole output, and raised it to a rate which had never been thought possible, and generally did the firm much good. Since then he has been to certain other firms, each job being a step upward in responsibility, and at each he has added to his knowledge of the problems of organising an aircraft factory, for at each he has had to evolve order out of chaos. And as witness to his success in handling men, it is worth noting that whenever he has left a firm to go to another the men under him have clubbed together to present him with some testimonial or other of their esteem and regard for a boss who has always given them a square deal. Therefore I submit that he is entitled to be accepted as understanding that about which he has written.

THE PUBLIC DEMAND.

While the articles were running in *The Aeroplane*, letters were constantly coming in from people in all classes, from managers of works who had recently been turned onto aircraft production, from mechanics, from women munition workers of the better class, from draughtsmen, and from school-boys, all anxious to know whether, and if so when, the series would be published in book form. It is now at their

disposal, revised in detail, with fresh drawings, and many more of them, by Mr. Geoffrey Watson, one of the most accurate and descriptive of aircraft artists.

A PROPAGANDIST WORK.

If these readers like the book I hope they will recommend it to their friends, and will so help to spread the interest in aviation which is so necessary if, after the war, the Government is to be forced by public opinion to maintain the huge Air Fleet which will be necessary to our future freedom from foreign domination. Mr. Blakeney's descriptions will show that an aeroplane, with its thousands of parts and hundreds of thousands of operations, cannot be built in a day. How much more necessary is it, therefore, to maintain after the war a strong and healthy Aircraft Industry, which will be able to supply the Air Force with all the aeroplanes it will need whenever it may need them?

Those in search of a moral will find that such is the moral of this little book. Those who are not interested in morals will, I am sure, find it very informative and interesting reading.

C. G. G.

CHAPTER I

POINTS OF ORGANISATION FOR GENERAL MANAGERS, WORKS MANAGERS, AND OTHER OFFICIALS.

In introducing the subject of the production of aeroplanes and their components it is necessary for those who have no experience in the Aircraft Industry that they should be given a slight insight into the works' organisation required, to enable them to grasp the fundamental principles and realise what position their abilities will permit them to hold. One can only be a general manager in name if one cannot manage, and this remark applies to all concerned holding lower grade positions.

Let it be assumed that a small but progressive and enterprising engineering firm are about to take up aircraft work. If the head of the firm is a practical man, who has given the subject of aircraft production considerable thought, which is very necessary before entering into this industry, he will have had to consider many difficult points in connection with this class of work.

POINTS TO BE STUDIED.

The principal points to be studied may be summarised as follows:—(a) The suit-

ability of his works and premises. (b) The suitability of existing machinery. (c) The purchase of additional new plant and tools. (d) The estimating for new contracts. (e) The placing of orders for raw materials. (f) The date for its delivery in and out. (g) The capabilities of his existing staff. (h) Their selection for various duties. (i) Whether it will be necessary to introduce a few experienced men to act as instructors. (j) The proportion of metal to wood workers necessary. (k) The utilisation of female labour, and accommodation for women workers. (l) The storage of timber and steel. (m) The arrangement of raw material stores. (n) The planning, progress, and inspection departments. (o) The finished parts, and methods of delivery.

Having enumerated the principal points, it will be well worth while to consider some of them in detail.

The works will now have, to a large extent, to be cleared of all previously used material, and possibly rearranged, and I would suggest that the simple process of window-cleaning be vigorously carried out, as it will probably cause many a scrap heap to come to light, and will enable the new work to be started under good conditions.

The workshops that are to be used for aircraft work should now be selected according to their adaptability for the work that is to be done in them.

THE ERECTING OR ASSEMBLING SHOP.

Naturally, the largest shop will be utilised for an erecting shop, that is to say, if the entrance is conveniently situated and arranged for large cases of goods being brought in or taken out for loading into lorries.

Headroom is also an important item if machines are likely at any time to be erected here, 16 ft. being a convenient height. It is also frequently useful if a steel joist runway is fitted up in a portion of this shop, as it enables engines to be easily handled and put into machines, and it is also useful as a means of attachment for weighing machines.

THE FITTING SHOP.

The fitting shop is the next shop that ought to be considered, for it is one of the first shops that should be equipped and started, as metal work takes a surprisingly long time to produce. Of course, many people will tell you it can be made very quickly and easily, but I have generally found that the first consignment of the "quickly and easily made" variety usually finds its way to the scrap heap quickly and easily.

Light and the arrangement of the benches should be carefully considered, as it is here that the largest amount of supervision is required, especially if the

hands are new at the work. The equipment should consist of $4\frac{1}{2}$-in. vices mounted on strong benches, about 4 ft. 6 in. apart, with one cast iron chipping block, 10 in. by 10 in. by 2 in. thick, to each three men. In addition there should be a metal jigsaw, with at least half a dozen 10-ft. coils of $\frac{1}{4}$-in. wide metal jigsaw blades ; a quick-work shearing machine with rotating cutters—power driven preferably ; a 36-in. guillotine to cut up to 8 gauge steel sheet—power driven ; a set of rolls for sheet metal work ; one 7-in.-bladed hand shearing machine ; one sensitive drilling machine to take $\frac{1}{4}$-in. twist drills ; and an annealing furnace of moderate size, with a pyrometer, gas-fired preferably ; also an acetylene welding plant for one or two operators.

This plant should be sufficient outfit for 10 to 20 workers where rapid production on small contracts is essential.

THE METAL MACHINE SHOP.

The metal machine shop should next be considered. This should be equipped with $6\frac{1}{2}$-in. centre precision lathes with self-centring and independent chucks ; $\frac{3}{4}$-in. and $\frac{7}{8}$-in. capstan lathes, and one $1\frac{1}{2}$-in. capstan lathe, all preferably with lever feed, and six adjustable stops ; a couple of good plain milling machines ; a vertical milling machine, and a dividing head ; a

tapping machine; an emery grinder and disc grinder; a universal cutter grinder; a couple of sensitive drills; and a good plain drilling machine to take up to $\frac{3}{4}$-in. drills. Also a 13-in. shaper is essential. A 10 or 20 ton power press is useful, as also is a heavy fly press.

The whole will be driven by the most convenient power available, and, where possible, will be placed on solid foundations, this being a matter of considerable importance for aircraft work.

THE SAWMILL OR WOOD MACHINE SHOP.

The sawmill should next be equipped. For breaking up large timber, a 36-in. saw is useful. There will also be an 18-in. circular saw; an overhand planing machine; a thicknessing machine; three vertical spindles with a speed not under 5,000 revs. per minute; a bandsaw; a jig-saw; a grinding machine for plane irons; a brazing apparatus for bandsaws; a disc sand-papering machine; and a horizontal sand-papering machine. A four-cutter is, of course, very useful also. Also a sensitive drilling machine, complete with wood drills.

This plant will be driven preferably with 20 per cent. excess of the power required, so as to have a good margin in case of an overload.

The placing of the machines in the saw-

mill should receive careful attention, and it is advantageous to lay out the machines on paper before they are fixed, as the long lengths of timber worked may cause considerable inconvenience when all the machines are working at once, and a considerable fall off in output will occur.

THE WOOD-WORKING SHOP.

The wood-working shop does not require much beyond the ordinary joiners' benches, except a few spar and longeron benches, which should be about 20 ft. long by 2 ft. wide to enable two joiners to work on them on each side. There should also be a drilling machine; a good grindstone for the wood-workers' tools; a steam box for wood bends; a gas-heater for glue pots; a large setting out table, 12 ft. by 6 ft., and glueing cramps on benches for hollow spar work.

THE DOPE SHOP AND COVERING SHOP.

The dope shop is a shop which requires special attention on account of the fumes which have to be removed. Reference should be made to the Home Office regulations. Also, heat is an important matter, and the heating apparatus must have ample proportions if delay in doping is not to occur.

The covering shop does not call for any special consideration beyond size, dryness

and cleanliness, and close proximity to the dope shop.

THE RAW METAL STORE.

The raw metal stores should be of ample proportions, with at least a 30 per cent. margin for expansion. To commence with, 300 Sankey bins, 14 in. by 14 in. by 14 in., are useful. These should, for preference, be built up in portable sections, double-sided, about 6 ft. by 6 ft. by 2 ft. 5 in.

Tubes and steel rods and bars can best be stored in a vertical position, where head room permits, with short vertical racks for short lengths.

Sheet steel should stand in vertical racks, arranged according to the gauge.

THE TIMBER STORE.

The timber store should next have attention. The site should be as close to the point of delivery as possible, and this again should be conveniently adjacent to the sawmill, otherwise valuable time and money will be lost in handling the large timber.

To prevent unsuitable timber from being cut up for component parts, it is best for someone who has had experience with the selection and conversion of timber into aircraft parts to examine the timber and superintend the stacking of all timber with

suitable grain and quality in piles, according to its suitability of grain for the various parts required in aircraft work. A notice should be nailed on a board, attached to each pile, specifically stating for what purpose each pile of timber is most suitable. This simple organisation will probably save the firm pounds, and also possibly their reputation.

The timber shed should be dry and airy, and all timber should be at least 9 in. off the ground, laid flat, and with frequent distance pieces of packing between each plank to admit of a free circulation of air between, care being taken to space the pieces out evenly.

ENSURING ACCURACY.

The fine limits of dimensions in aircraft work necessitate the machinery being in an accurate working condition, and a thorough examination of it is necessary. Inaccurate machines must be made accurate or scrapped, those not suitable being replaced by machines that are. This will involve promptly selecting and ordering the new machinery required. The firm will also require micrometers; a couple of steel tapes; wire gauges; protractors; and flexible steel rules, preferably marked in decimals and millimetres.

ORDERING MATERIAL.

The special steel required, both sheet and bar, nuts, bolts, etc., must be now ordered and obtained. These must be strictly in accordance with the specification mentioned, and should be ordered by the planning department after a careful examination of each plan of component parts, and the list checked.

The timber required should also be ordered, and a selection by a competent specialist made before delivery.

SELECTION OF STAFF.

The selection of the staff for the various departments and posts therein will require careful consideration. The first men to be selected should be for the planning or organising department.

These men should be trained draughtsmen, who preferably have had workshop training, as they must be capable of reading a drawing and producing one, together with dimensioned sketches of parts required, and drawings of the necessary jigs. These men can, with advantage, be divided into four groups, namely, those experienced in metal working, those experienced in wood work, and those experienced in tool and jig work.

One or two others with a fair general knowledge will be allocated to the duty of

recording the works' production orders issued to the works; the drawings accompanying them, and the date on which these are issued; ascertaining the date on which production should commence; and reporting each day to the manager those items on which production is not in accordance with the schedule of parts required.

This system, if carefully organised and rigidly carried out, will be found to be of the greatest possible value to all concerned in production, and will prevent delay in the erecting and other shops. Thus, it may be looked upon as a valuable step towards rapid production, as those items which are behind time will at once have the attention of the manager and the foremen. These officials will scrutinise the cause of delay, and the method of production, and, if necessary, will change it at the earliest moment or remedy the material which may be faulty, or alter the jigs, and thus prevent " scrap " from being made.

FITTING SHOP PERSONNEL.

The foreman of the fitting shop should next be selected. He should be chosen for his superior knowledge of metal working, his appreciation of accuracy in detail, and, if possible, his ability for reading drawings correctly, together with his

faculty for leading his men, and controlling their methods. Under his control should be placed a first-class marker-off, whose duty will be to mark off accurately all templates on black iron sheet, or other available metal. When he has set to work press tools can be put in hand if the quantity of aeroplane fittings required is sufficiently large. With this man, a first-class template maker should be set to work, whose duty it will be to produce truly and accurately all templates for sheet metal parts that have to be made, and a tool maker for making drilling and other jigs.

These, when completed, should be carefully checked by the inspection department and stamped. They will then be ready for the use of semi-skilled hands, who will roughly cut out and finish off the sheet metal parts, which will then be passed on to the skilled metal workers to complete.

ARRANGEMENT OF HANDS.

The skilled metal workers should next be selected. These men, being trusted workers, may, with advantage to the foreman, be placed in the part of the shop which is most difficult for him to supervise. Near them should be placed the bench for the best of the unskilled workers, and close to the foreman's office,

or in the part of the shop most accessible for supervision, should be placed those workers who have the least experience. This system has been tried and has given excellent results, and can be recommended for a trial.

Female labour should preferably work in a separate part of the shop, there being many jobs, such as bending wiring plates, stamping the drawing number and part numbers, cleaning off scale after annealing, cleaning up castings, rough filing small light-gauge parts to a plus size template, which can be undertaken by them with success, also drilling holes and reamering.

EXPERIENCED HANDS.

With regard to the introduction of men experienced in aircraft work, this is, of course, a matter best left to the judgment of the management, but, if the management themselves have had no practical experience of aircraft work, then experienced men as instructors or inspectors must be introduced. It is not then in the interest of the management to interfere with them or criticise their methods, excepting when they fail to produce finished work.

If you do honestly see ridiculous systems or methods employed by these men, then you can say to yourself that

you have also failed; that is, by selecting the wrong men. These remarks can well receive the consideration of the management of some few works, and be taken to heart by them. In other words, "Don't interfere with things you know nothing about. Leave them to the specialist."

Have you not scoured the advertisements in *The Aeroplane* for weeks to find this "specialist," has he not undergone an inquisitorial examination before your board of directors, and has he not been told that his services will be accepted on account of his previous experience, and on condition that if he fails, penalties almost equal to those of the Spanish Inquisition will be inflicted on him?

PROPORTION OF WORKERS.

The proportion of metal and wood workers to erectors and coverers is one that requires thought and judgment and a keen grasp of the rate of production, for money and temper will inevitably be lost if this important matter is not properly dealt with. Remember that wood work is produced at double the rate of metal parts for the same number of hands.

THE INSPECTION DEPARTMENT.

The firm's own inspection department is a department that should be organised at once, as it may be regarded as a safety

belt for the firm, to prevent it from dropping into the sea of disapproval of the A.I.D.

A well-lighted quiet room, with a well-finished bench and lock-up drawers, a vice and a few stools, are required, with a nest of bins and drawers capable of holding copies of all the drawings which are issued to the works. These should be filed in batches, each batch constituting all the drawings of a complete component part, such as a rudder, or a fin. A separate drawer or drawers should be kept for each contract. Don't mix them all up, it wastes too much time.

The inspectors should be chosen because they know their trade. We will take first the inspector of wood parts. He must be a skilled wood-worker, used to high-class accurate finish. If you can get him, have one who has been used to pianoforte manufacture. Next ascertain if he is a keen judge of timber and knows what constitutes sap and decay, or dead wood, and find out what he would do with a pocket of resin. Would he pass it, or not?

He must also be well used to, or capable of, measuring up parts with dead accuracy, hundredths of an inch count, and so does shrinkage of newly worked timber. A $\frac{1}{32}$ in. full is better than $\frac{1}{100}$ in. under size. Also, it may save your firm money if he remembers that ash is a hard wood,

but it shrinks. I once was told that it did not, but I don't believe so now. Also, a short cross-grain will not do for spars, inter-plane struts, and longerons, only long straight grain being suitable.

Ask him how he would test a finished wing spar without damaging it? There is one very simple way that works all right; take it up with both hands, hold it level with your chest, and shake it vigorously.

He should also have a knowledge of the various makes of glues, and how to prepare them for use. Certain glues now in use in aircraft work require careful treatment and must not be over-heated. If they are, they will be spoilt, and bad joints will result. Also glue must be made fresh each day, and the glue pots cleaned out thoroughly.

The inspector of metal work may now be considered. He must be an all-round first-class mechanic, and preferably have had experience in both machining and fitting. He should also be thoroughly accustomed to the use of a micrometer, gauging, accurate setting up and marking off, and he should appreciate what it is to have to work to a five-thousandth of an inch.

THE INSPECTORS' POSITION AND EQUIPMENT.

The importance of the posts held by the firm's inspectors should be recognised by

the firm for whose reputation and interests they are working, and the inspectors' reports should receive the careful consideration and attention from the general manager and works manager that they deserve. Also the inspectors themselves should realise and appreciate the position they hold, and act accordingly.

The firm should supply the inspectors with a reasonable kit of tools to enable them to measure accurately the component parts, and experience has shown that the following may be considered a useful selection. For our purpose, we will take up either a Brown and Sharpe or Starretts' catalogue of small tools. In this case a Brown and Sharpe small tool catalogue, No. 25A, is to hand. From this the following tools may, with advantage, be ordered :—Micrometer calliper, No. 2, English measurement, 0—$\frac{1}{2}$ in., with rachet stop, for strainer work ; micrometer calliper, No. 10, English measurement, 0—1 in., with rachet stop ; micrometer calliper, No. 30, English measurement, 0—2 in., with rachet stop ; micrometer calliper, No. 235, rolling mill gauge, English measurement, 0—0.400 in., with rachet stop ; inside micrometer calliper, No. 250, 0.200—1 in., English measurement ; inside micrometer calliper, No. 252, $\frac{1}{2}$ in.—1$\frac{1}{2}$ in., English measurement ; B. and S. combination square, with-

out centre head, No. 401, size 6 in.; B. and S. protractor, with reversible protractor head, size 18in., English measurement; improved bevel protractor, No. 493, 12 in. blade; vernier calliper, No. 570, English measurement, size 6 in.

THE INSPECTOR'S DUTIES.

The general duties of the Inspection Department are to inspect and pass all raw material; to see that none but passed materials are issued to the works; to look for and investigate and report on all unsatisfactory material, and stop further use at any stage of its conversion into finished parts; to inspect all parts when finished, before they are passed to the A.I.D. for inspection; to watch the assembly of all such component parts as fins, rudders, tail planes, elevators, and fuselages, and see that no parts are used that are not passed by the A.I.D.; and to see that all rejected parts made by outside firms are returned to stores with a label attached, stating the name of the maker and the precise cause for rejection, so that the firm concerned may know the cause for rejection.

A list should be sent each day to the works manager containing:—

(1) Lists of parts rejected due to faulty workmanship, and being under size, with name of workman and department.

(2) Parts rejected due to faulty material, with maker's name.

(3) Parts rejected due to drawing alterations and modifications.

(4) Lists of parts or material required to be replaced, owing to being scrapped.

PLANNING DUTIES.

The duties of the Planning Department may next be considered. It may be briefly said that it is their job to ascertain the best way to do a job and to detail the operations. For this purpose an instruction-sheet should be issued to the works with each order and drawing, and it should not be left for the workman to find out. Thus, work should not go to the fitting shop first, when it should go to the machine shop.

They will also keep records of material in store, and order all special material that is required and specified when looking through the drawings. They will also issue the drawings in the rotation in which the parts will be required in the erecting shops. This will save the erecting shop from getting the last thing first and the first thing last.

THE PROGRESS DEPARTMENT.

The Progress Department will receive these orders and see that the parts are produced in proper rotation in quantities

as required. They will keep track of all orders in the shop; record daily progress, and report each day to the Works Manager any parts that are getting behind.

Orders for work requiring special precedence over other work will be dealt with on special orders, which have some identifying mark or colour, to distinguish them from the ordinary work.

FINISHED PARTS.

The Finished Part Stores should be separate from all other stores, and should preferably be near the Inspection Department. From here all parts required by the erectors should be issued, and from no other stores. This is essential, as it prevents parts which have not been passed by the A.I.D. being issued to the erectors, which is of the greatest importance.

CHAPTER II

GETTING TO WORK.

Having dealt at considerable length with the outline of the organisation required in any works, in a more or less modified form, for producing aircraft parts, we will now assume that orders have been issued by the General Manager to the Works Manager to proceed with the immediate construction of ten tractor biplanes of any ordinary commercial type.

For the sake of getting quick-finished production and deliveries the orders may be issued for two batches of five. The necessary orders having been issued to the Wood Machining Department for the wood to be cut and machined for five complete sets of wood components, the most suitable timber will be carefully inspected and selected from the pile.

BEGINNING THE FUSELAGE.

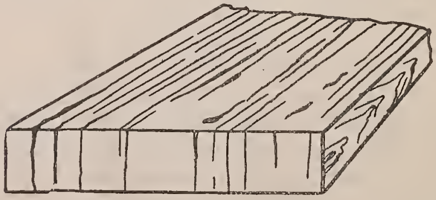
In this case we will assume that the fuselage is the unit selected for the start. The timber required in this case is spruce, about $1\frac{1}{4}$ in. square tapering down to 1 in. square to form the longerons, the length being about 19 ft. in two lengths.

The spruce selected should preferably

have a fine grain, which, when the longeron is in its permanent position, should form vertical laminæ, as it develops the greatest strength in this position, and also adapts itself to the curves or bends required in forming the streamline contour of the fuselage. The wood might also be selected for its cream-like colour, as this coloured wood is generally found to have the qualities required.

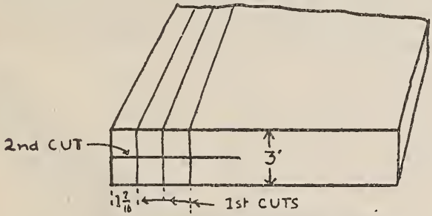
SAWING UP.

Having chosen a 3 in. plank with a fine grain of horizontal or vertical laminæ, not less than eight in number, if possible, the plank can be taken to the circular saw and cut into $1\frac{7}{16}$ in. battens by 3 in. These will be laid on their 3 in. face, and again cut down the middle into the approximate section or size required, namely, in this case, $1\frac{7}{16}$ in. by $1\frac{7}{16}$ in. Cut this way, it will enable the "rift sawn," or vertical, grain (see Fig. 1) to



RIFT SAWN TIMBER
FIG. 1.

be obtained as required. To make the whole operation clearer the sketches may be referred to. (See Fig. 2.)



CUTTING LONGERONS
FIG. 2.

The timber having been rough-sawn to size, it may be as well for the Works Inspector to see it before further work is done to it, and satisfy himself about the quality. Assuming this to be satisfactory, it then may be passed on to the planing machine and have its sides squared to $1\frac{9}{32}$in., which will be the margin required for shrinkage.

A LONGERON JIG.

If the foreman of the wood machinists' shop is a quick energetic man, he will now make a simple jig (see Fig. 3) for tapering these battens from $1\frac{9}{32}$ in. at one end to $1\frac{1}{32}$ in. at the other end, in the following manner:—Get a piece of hard wood, about 20 ft. by 6 in. by $\frac{1}{2}$ in. The top and bottom surfaces and

one edge of this must be planed true. Next, place the longeron on this hard wood batten and equalise its position on the batten at either end. After having cut the longeron about $1\frac{1}{4}$ in. longer than its

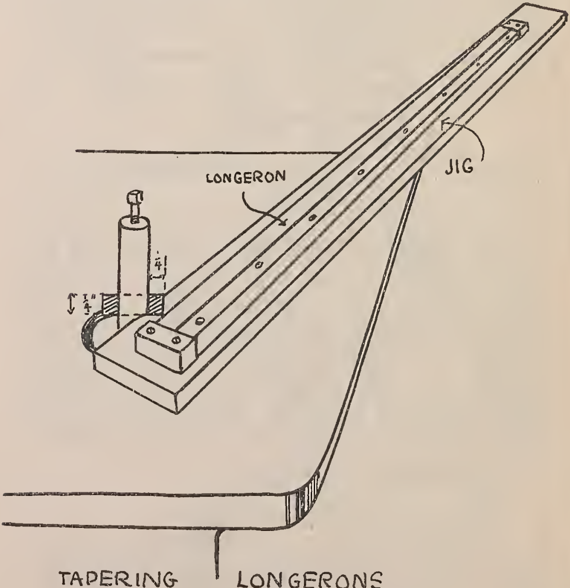


FIG. 3.

correct length, one end should be clamped down at $\frac{1}{4}$ in. from the straight edge of the batten and the other end flush with the edge. Test the straightness of the

longeron and fix it with a few additional clamps. Having assured yourself that the longeron has no curves in it, get another piece of hard wood the same length as the longeron, and perfectly true, about 1 in. by 2 in. section, and lay it along the back of the clamped longeron. Then glue and screw it to the hard wood batten and place a cross stop at each end to keep the longeron correctly in its bed in the jig. This jig will then hold the longeron in position when being machined.

Whilst the longeron is being passed across the French vertical spindle, the cutter of which is adjusted to project exactly $\frac{1}{4}$ in., it follows, therefore, that if the edge of the hard wood batten is pressed against the spindle underneath the cutter, commencing at the end where the longeron is $\frac{1}{4}$ in. from the edge, no cutting of the longeron will take place, but as it is slowly pushed past the cutter, the cutter will begin to remove the required amount, continuing to do so until the end of the longeron is reached, which is what is wanted, and the maximum $\frac{1}{4}$ in. at the end is removed.

When the longeron is now measured it will be found to be $1\frac{9}{32}$ in. at one end, tapering to $1\frac{1}{32}$ in. at the other end, which is exactly what is required. Repeat the whole operation on one more side and the longeron will be found to be

the correct finished taper, namely, tapering from $1\frac{9}{32}$ in. square down to $1\frac{1}{32}$ in. square. This work can also be done on the planing machine in a horizontal jig.

The longerons can all be worked this way and passed to the inspection department as completed, to be inspected, passed, and stamped ready for issue to the erecting shop, where the longeron will have to be cut in two as the fuselage is built in halves.

It may be advisable for the above longerons to be machined in two separate lengths.

FUSELAGE STRUTS.

The next component parts to be considered will be the struts for the fuselage. In accordance with modern practise and design, which we can assume has been adopted, they will be square section, tapering from about 1 in. each side of the centre of the length to the ends on all four sides, and fluted on two sides.

For our purpose we will assume that the lengths vary between 3 ft. and 1 ft. 3 in., and that the centre section is $1\frac{1}{8}$ in. square, diminishing as the rear end of the fuselage is reached to $\frac{7}{8}$ in. square, all tapering at the ends to $\frac{3}{4}$ in. square, where they bed and fit into the steel fittings on the longerons.

The timber for the struts may be cut

from any straight grain plank, care being taken to select as far as possible a good fine grain for the long struts. The plank being taken to the circular saw, the required number of pieces of each size are cut, each about $\frac{1}{8}$ in. larger in section than the finished size to allow for planing up to $\frac{1}{32}$ in. above size.

These lengths of timber can now be cut about 1 in. longer than the finished length and sent to the setter-out, who will, before working on them, submit them for inspection. After they have been passed for quality, the setter-out will find the centre of each and mark off 1 in. each side of the centre of the length. This is where the lightening begins, the lightening being $\frac{5}{16}$ in. deep and $\frac{3}{8}$ in. wide, finishing about $1\frac{1}{2}$ in. from each end of the correct length.

This having been done, they will be taken back to the wood machining department to have the four lightenings (two on each of the two opposite sides) cut out on the spindle.

A STRUT JIG.

The first strut having been completed, it will be at once sent off to the wooden jig maker, who, after carefully consulting the drawing, will at once proceed to make the jig (see Fig. 4) for holding them whilst they are tapered on the vertical spindle.

This jig will consist of a hard piece of wood about 6 in. longer than the strut, 4 in. wide by $\frac{3}{4}$ in. thick. The centre of this will be carefully squared off, and 1 in. one side of this marked, corresponding to the beginning of the lightenings each side of the centre portion of the strut. Next, lay the strut on the board, with the centre of the strut corresponding to the centre of

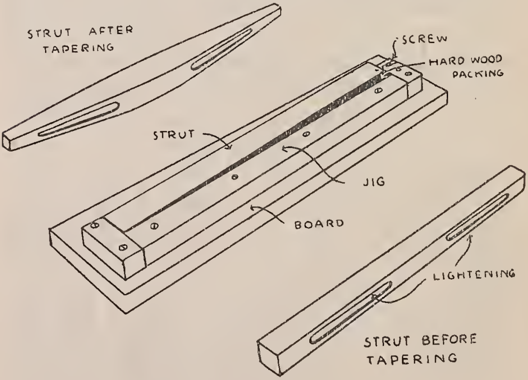


FIG. 4.

length marked on the jig board. Set strut back $\frac{1}{4}$ in. from the edge where the lightening begins, and $\frac{1}{16}$ in. from the edge where the correct end of the strut occurs. Clamp the strut firmly in this position, and then fix another piece of hard wood on the inside of the strut, glueing and screwing it to the 4in. by $\frac{3}{4}$ in. jig

board. Cut off the ends true and fix a cross strip across the board with a screw projecting through it horizontally, with the point filed up to a sharp chisel edge. This is for the purpose of gripping the strut in the jig.

TAPERING A STRUT.

The jig now being ready for operation, it can be given to the spindle hand. He will take a strut, lay it on the jig, press it against the longitudinal strip, and force the end on to the chisel-pointed screw (see Fig. 4), the cutter in the spindle being about $1\frac{1}{4}$ in. wide, projecting $\frac{1}{4}$ in. On pushing the jig board past the cutter, pressing the jig board against the spindle, the cutter will remove the first side of the taper. This being done, remove the strut, and lay against the longitudinal fixed strip a tapered strip of hard wood packing, corresponding in size to the quantity of wood previously removed by the cutter. This will pack out the strut and enable the cutter to remove the portion on the opposite side.

Two opposite sides are now completed, and all that it is necessary to do is to repeat these operations on the remaining sides at each end and the strut will be finished, all except cutting to the dead length.

The above mentioned operations refer to all struts, the only other difference being

that jig boards will be required for each strut of a different length, as the taper varies slightly. This work can also be done on a jig board, which holds four struts on the planing and thicknessing machine.

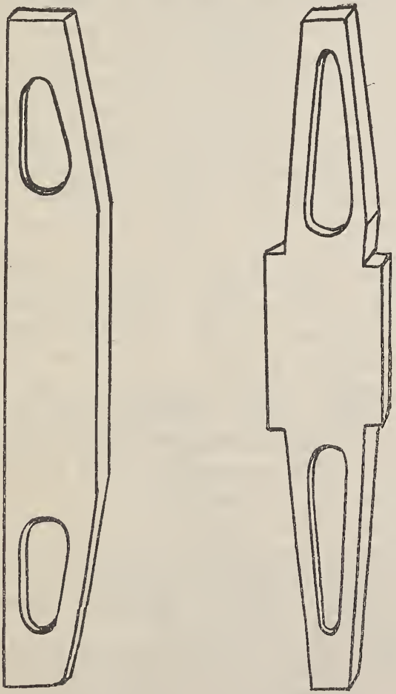
FRONT END STRUTS.

At the front end of the fuselage we will assume that four ash struts are required, two each side, for stiffening the fuselage and attaching the engine plate. These will be flush on the inside and sunk and lightened on the outside, right and left-handed. As these struts have to bear considerable strain and vibration, quality of timber and fine straight grain is again essential. The front struts will be about 2 ft. $5\frac{1}{2}$ in. long, 5 in. wide and $1\frac{1}{4}$ in. thick, with the ends tapered down, on one edge only, to $3\frac{1}{2}$ in.

Commencing at 7 in. from each end, the "sinking," or lightening is commenced at $7\frac{3}{4}$ in. on either side of the centre of length and is carried towards each end of the strut, diminishing in width as the end is approached, the lightening stopping at $2\frac{1}{2}$ in. from the end (see Fig. 5) with a margin or flange at the sides $\frac{3}{8}$ in. thick.

Before cutting up an ash plank it will be best to get the wood setter-out to mark off the outline of the strut on a mahogany board, taking care to leave an excess of at

least $\frac{1}{8}$ in. on all sides of the outline to allow for shrinkage and cleaning up.



ASH FUSELAGE STRUTS

FIG. 5.

The template having been cut out and completed and checked by the inspection

department, with the drawing, it will be sent to the wood marker-off, who will go to the machining shop and mark off the outline on the selected ash plank, which can then be taken to the band saw. These ash struts may then be cut out, after which they can be sent to the wood-finishers' benches to be finished and then passed on to the marker-off to set out the lightenings, which will be done on the spindle, in two cuts.

CROSS STRUTS AND FUSELAGE SPARS.

We can assume that the cross struts for the front part of the fuselage consist of $1\frac{1}{4}$ in. square spruce, which must again be of exceptionally good quality, and long, fine grain. This must be cut from a selected plank and put through the thicknessing machine, after which it can be sent to the wood-finishers' benches to be cut up into the correct lengths, plus $\frac{1}{8}$ in. to allow the erectors to fit and bed the ends to the top longeron and the front bottom fuselage spars which form the bottom longitudinal members of the fuselage.

These will be of ash, about 6 in. deep by $1\frac{1}{4}$ in. thick, and, say, 6 ft. 6 in. long, tapering down to $1\frac{1}{4}$ in. square at the rear end, with three lightenings in the centre, each side (see Fig. 6).

A template of this should next be made, not forgetting the $\frac{1}{8}$ in. full over finished

dimensions to allow for shrinkage and cleaning up to $\frac{1}{32}$ in. full. The template being made, the marker-off will mark off the outline on the ash planks. These can then also be sent to the band saw and then sent to the wood-finishers' benches. The ash struts and the front bottom fuselage-spars can all now be taken to the marker-off, who will outline the lightenings in pencil, and then they will be sent to the wood machining department to have the lightenings cut out on the French spindle, each lightening being done, half at a time, and reversed upside down to finish the uncompleted half.

ASH FUSELAGE SPAR

FIG. 6.

We will assume the lightening is $\frac{3}{8}$ in. deep each side, and the radius at the sides $\frac{1}{2}$ in. The spindle work being done, it may be necessary for them to be sent to the wood-finishers to have the lightenings cleaned out where the spindle did not reach, as is sometimes the case. After this has been done the whole lot can be sent to the inspection department to be passed and stamped.

THREE-PLY TIES.

On the assumption that the design of the machine is fairly modern, and as adopted in a few cases, we will arrange for the front part of the fuselage to be tied together with $\frac{1}{8}$ in. three-ply, with lightening holes cut out in accordance with the plan. These will be set out on one sheet of three-ply, which should be large enough for this purpose, to avoid joints, which would constitute a grave weakness.

The first sheet having been outlined and this passed, it can be laid on ten other sheets and the lot fastened together with fine wire nails, which should be plentiful, and placed principally on the part of the three-ply to be cut out, about 2 in. pitch.

If this is not done, damage may be done to the edges of the three-ply by the jigsaw. After this is done the sheets of three-ply will be taken to a drilling machine, and 1 in. to $1\frac{1}{2}$ in. holes should be drilled in each lightening to be cut out, to enable the jigsaw operator to pass the jigsaw blade through.

When all the lightenings have been cut out, the sheets can be sent to the wood-finishers' benches to be cleaned up, ready for passing by the inspection department, and put in the finished part wood stores ready for issue to the erecting shop.

The next part to be provided will be the

ash distance pieces for the rear portion of the fuselage in line with the front spar of the tailplane, these will be of ash and be about 1 ft. 3 in. long by 5 in. wide by 1 in. thick, lightened out, this work being done in a similar manner to the front ash struts.

The three-ply covering at the top and bottom and sides of the fuselage for strengthening and tying the rear end of the fuselage together can be now cut out in the same manner as described for the front ends.

THE STERN POST.

The ash stern post can now be put in hand. This will have to be of exceptionally good material, to avoid being rejected. It may be assumed that it is about 1 ft. 8 in. long by $4\frac{1}{2}$ in. by $1\frac{1}{2}$ in., with bevelled edges, to suit the contour of the sides of the fuselage, this will preferably be cut out of a rift-sawn plank (see Fig. 1), as the grain in this case will afford the most suitable strength.

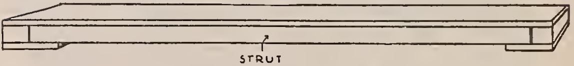
The upper portion of the post being cut away each side on the band saw, and finished on the bench, the bevel can be done on the planing machine or on the French spindle.

UNDER-CARRIAGE STRUTS.

The struts for the landing chassis can now be put in hand, these must be made from spruce of clean straight grain, which

is the extent of the specification for struts for this purpose, of course free from resin and any shakes, the length being 4 ft. 2 in. by $7\frac{1}{2}$ in. by 2 in. streamline section with ends cut and bevelled on two angles to support the fuselage, and the other or lower end to be fitted into the sheet steel fitting.

The timber having been selected and the template of the outline having been cut out $\frac{1}{8}$ in. full, the outline can be marked out off the template onto the spruce plank, which has been cut down from a larger and thicker plank, and planed up both sides to $2\frac{1}{8}$ in. thickness. It is then taken to the



BOX JIG FOR SPINDLING STRUTS

FIG. 7.

band saw and cut out to the outline, leaving each end 3 in. long, after which it is necessary to finish it up to the approximately finished streamlined section and dimensions, which can be done on the spindle, in a semi-box jig which covers the strut to be spindled, but which supports it and holds it in position (see Fig. 7), the edge of the jig which presses against the spindle being curved or contoured according to the design of the strut.

A BOX JIG.

The jig will consist of a board about 5 ft. long 9 in. wide by 1 in. thick. At a distance apart of 4 ft. 8 in., securely fix two stout cross-battens about 9 in. by 3 in. by 2 in. to the board, on the top of these cross-battens, glue and screw a piece of hard wood 9 in. by 4 in. by $\frac{1}{2}$ in. so as to form a rabbet of the cross-battens, and along one edge of the board on the same side as the cross-battens glue and screw a longitudinal batten or strip $1\frac{1}{2}$ in. wide and 2 in. thick.

Into this space the strut is placed and the cutter of the spindle having been accurately ground up to a contour of a quarter of the whole streamline, all that has to be done is to pass the jig containing the strut in its unformed state past the cutter on the spindle. A quarter of the strut is now practically formed accurately; the next thing for the spindle hand to do now is to slide the strut out and do the opposite side in a similar manner. One half of the strut is now complete, namely, the side next to the table of the spindle. Take out the strut, reverse its position in the jig and replace the cutter for the one for the rear side, and repeat the two previous operations, and the machining is complete, it can now be sent to the wood-finishers' benches to have the ends

trimmed, and to be cut nearly to the required length.

ASSEMBLING AND ERECTING.

The erection of the rear half of the fuselage can now be commenced, and, for the purpose of this article, we can assume that the fittings have been made, and that the swaged tie-rods, fork-ends, and nuts are in stores, also all necessary bolts and nuts.

Owing to the design of the fuselage, the best way will be to assemble the bottom part of the fuselage first in a jig. To do this, it must be built upside down, to permit of the three-ply being glued and screwed down on the bottom side at the rear end.

A jig being a mechanical apparatus for enabling labour to produce interchangeable component and whole parts, it follows that as much care and thought, and sometimes expenditure of time and material, must be spent on it, as the cost of producing perhaps two or three of the required component parts by other methods, which invariably fail in producing repetition work accurately. To start with, ordinary wooden setting-out tables are useless, for however tightly the boards are clamped together, and cross-battened underneath, expansion and contraction always takes place; therefore, until a

better method is generally known, it is best to cover the top, on which the setting out is done, with three-ply about $\frac{3}{16}$in. thick, as the contraction and expansion of this material is negligible, and upon this jig work can be developed and built up.

AN ASSEMBLING TABLE.

Therefore, we can proceed to build the table of $\frac{3}{4}$ in. or 1 in. "flooring," well clamped together and screwed to cross battens with about 3 ft. centres, of the same material. It should then be put into the shop, where it is to remain permanently, carefully laid and bedded horizontally on about four trestles, as the length will be about 12 ft. 6 in. long by 4 ft.

There it should, if time permits, be allowed to remain for two or three days to season, after which the top should be carefully tried for level with a straight-edge, in the following manner. Try each side and each end, and try it square across the centre, then diagonally from corner to corner, and make it true to all these tests.

It may then be covered with the three-ply, which should only be screwed down with just a sufficient number of screws to hold it evenly and firmly down to the table. Do not attempt to plane the top surface if uneven. Three-ply, $\frac{3}{16}$ in. thick, won't stand this. Take it up and alter the deal boards below.

Having prepared and finished the table, plane one edge of it carefully, and test it with a straight-edge until it is true. This edge is wanted by the setter-out from which to use his square, and as a base-line. Also, don't trust to squares; only about one in ten is dead true. After you have set out a line at right angles to a base-line, test it. This can be done by the following method, which most men know.

Measure off on the base-line any four units of length, and three of the same units on the line to be checked, the third side or hypothenuse of the triangle should equal in length five units. This is known as the 3—4—5—method, and these units may be inches, feet, yards or miles. The method is based on the old 47th Prop. of the First Book of Euclid, which proves that the sum of the squares of two sides of a right-angled triangle are equal to the square of the hypotenuse, or side facing the right angle. Thus $3^2 + 4^2 = 5^2$, or $9 + 16 = 25$, so the angle between 3 and 4 must be a right angle.

Check these distances with the use of fine trammel points if possible. If this last measure does not meet the extreme points of the other measurements exactly, then the line which is supposed to be at right angles to the base-line is incorrect, and a further check must be made.

SETTING OUT.

We can now proceed to study the plan of the fuselage, preparatory to setting it out on the jig table. Having done this, the first thing to do will be to find accurately the centre of the table. Mark these points with a soft pencil, then check each of these points from the base-line, or trued edge, of the table. If they are not dead accurate, alter the point so that each point is absolutely the dead same distance from the base-line as the other. This is most important, and if not given minute attention, may cause endless trouble and perhaps cause the bottom part of the fuselage to be so out of square and inaccurate as to necessitate it being scrapped. It may only be $\frac{1}{8}$ in. out, perhaps only $\frac{1}{16}$ in., but it is wrong, and, as wrong, it will be rejected. Excuses of any kind cannot, and will not, be tolerated.

It is best, owing to the accuracy required, for the setter-out to provide himself with a pocket-knife with a conveniently shaped handle, and, after having found the points approximately with a pencil, to mark all measurements permanently with a fine knife cut, after he is satisfied they are correct. Pencil marking is useless for real accuracy, but must be used when setting out spars.

Having found the centre of the table at

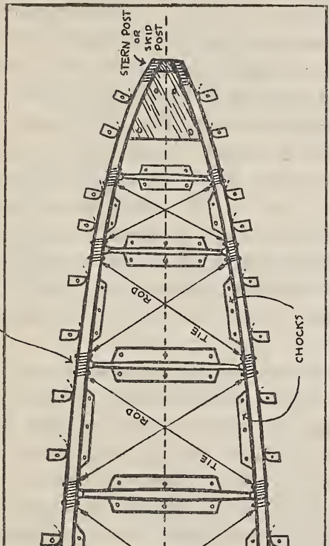
each end, lay a straight-edge along the table and with the pocket-knife draw or cut in once only a fine centre line. You can then go over this with a pencil to make it more clear. Next, set out the position of the true ends of the longerons, where they join up to the front half of the fuselage, then put a line square across the table about 4 in. from one end. This will enable the longerons to be accurately placed in position when the time comes.

It will be well to pencil on this line, for the general information of all concerned, what it is for, to prevent mistakes. From this point, the distance to the centre line of each cross strut should next be marked, and when these are all done, put a square line across, cutting each point.

Next refer to the plan, and from that obtain the cross widths between the longerons at each cross strut. Carefully put a cut line at each end, this will enable you to set the longeron out accurately in plan on the table, and get the correct contour. (See Fig. 8.)

LAYING ON.

Having done this, lay on one longeron and clamp it to these marks; then the second; after which take a steel tape and accurately check all your distances in between the longerons at each strut, taking care to do this on the centre-line of each



FUSELAGE JIG AND COMPLETE PORTION.

FIG. 8.

strut, and not at the side. The centre-line may with advantage be marked in fine pencil on the longeron (cutting with a penknife in this case is not permissible).

Having adjusted any inaccuracies, small pieces of hard wood about 4 in. by 2 in. by 1 in. may be fixed down by means of glue and screws to the table, being gently pressed against the longeron until their position is definite, and the glue sufficiently set. When this has happened they can be further secured by means of a couple of screws.

The position of these distance pieces from either side of the centre-line of the strut should be determined by the length of the steel fittings, and a small margin of, say $\frac{1}{4}$ in. each side allowed for freedom.

Having fixed all these stops, hard wood turn-buttons should be fixed outside the longeron—(see Fig. 8)—to press it against the stops, when it is being finally fitted, not forgetting to use a piece of three-ply to prevent damage to the longeron. These turn-buttons are desirable on jigs, because they permit of quick release of longerons, struts, and other parts.

STEAM BENDING.

The bending of the longerons to fit the contour required by the jig will entail the use of a steam-bending plant, using low-pressure steam; preferably about 10 lbs. per square inch.

The steam-box should be long enough to take the whole of the longeron, for it is necessary to steam the whole longeron before bending. Care should be taken that the grain lies vertically when the bend is completed. If this process is not carried out crushing of the fibres will occur, and the strength destroyed.

The steam-bending plant must be close to the jig, for the value of steam-bending will be lost if the longeron is allowed to get cold on being taken out of the steam-box before it is put into the jig. The transference from steam-box to jig should be made as quickly as possible, and the longeron should be allowed to cool in position for a few hours.

FITTING UP.

Having got the longerons laid out on the jig table accurately in position, and all measurements carefully checked, the next thing to do will be to fit the steel fittings on to the struts, taking care in doing so that an equal amount is cut off each end of the strut, measured from the centre, especial care being taken to see that the strut beds accurately and squarely into the fitting. When this has been done the strut should be tested in between the limits of a " length jig " made up to represent a short length of fuselage—(see Fig. 9)—with a sliding adjustment, which can be locked to

any required measurement or angle within limits.

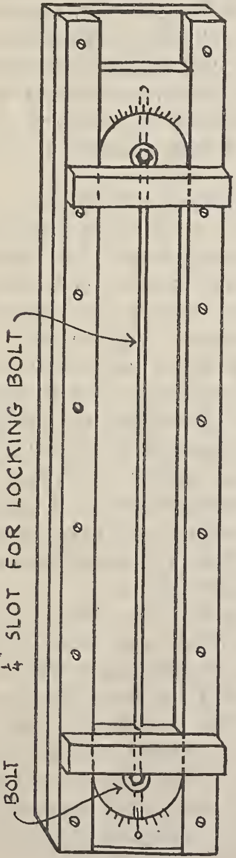
A LENGTH JIG.

This kind of jig will be found useful for checking many classes of work, and a few of varying lengths can be made with advantage. They can, of course, be elaborated to suit special requirements.

The strut and steel fittings having been tested for length and found correct, the strut should be tried in between the actual longerons for fit, and it should go in with a gentle pressure. When it is in its final correct position the bolt-holes in the fitting should be very carefully marked off on the longeron for drilling; this can be done with advantage by using a piece of steel exactly fitting the bolt-hole, about 4 in. long, and slightly countersunk, like a rivet-snap, and giving the piece of steel a few light taps to mark the longeron.

This having been done, pencil a distinguishing mark on the strut and on the longeron, so that it will be picked out again and put into the same place in the same fuselage. Preferably use a rubber stamp.

All struts will be fitted in this manner, and after this work is completed, each longeron should have the position of the fittings and the bolt-holes marked out for the vertical strut fittings, after which the longerons should be taken out of the jig and the bolt-holes drilled on a drilling



LENGTH GAUGE

Fig. 9.

machine with the aid of a metal plate jig clamped to the longeron to prevent the holes from being drilled out of centre. As no inaccuracies in bolt-holes in wood work are permissible, extra care must be taken with the drilling, and wood drills used, twist drills not being suitable.

GETTING TOGETHER.

All the various bolt-holes being drilled, the longerons will at once be returned to the erecting shop. Here the longerons, being of spruce, should be neatly bound with $\frac{1}{2}$-in. India tape, tightly laid on after the surface has been well covered with glue, and also the tape, each layer half overlapping the previous one and the end secured by a couple of $\frac{3}{8}$-in. by 20 gauge brass gimp pins, after which all surplus glue may be removed with a damp rag. This binding is only required where the steel fittings are placed, and should extend about $\frac{1}{2}$ in. either side.

The longeron will then be replaced in the jig and the final assembly of the rear bottom part of the fuselage will be commenced. It will be best to put in the shortest struts first and work forward, as this method will secure the ends of the longerons having the sharp curves fixed first, and also it will enable another couple of erectors to fit, glue, and screw down the three-ply at the rear end.

SIMPLE HINTS.

In bolting the fittings on, it is usual in seaplane work to give the bolts a coat of enamel, and tap them home, to dry in position, as the corrosion by salt water on steel fittings is very severe indeed. This helps to increase their life, and might as well be done in all aeroplanes. In tightening up bolts, it is well for erectors and others concerned to bear in mind that the size of the bolts they are handling are anything between $\frac{1}{8}$ in. to $\frac{3}{16}$ in. B.A. threads and $\frac{1}{4}$ in. and $\frac{3}{8}$ in. B.S.F. threads, therefore it is not necessary to use a yard of 2-in. gas piping on the end of the spanner as a lever or to send for the "heavy gang" or millwrights, with 14 lb. slogging hammers, to drive the bolts home or lock up the nuts, as such methods are likely to smash the bolt or crush the head or nut into the soft wood. They would also put unnecessary strain on the bolt, and such methods do not find favour with the A.I.D. Also, incidentally, it may cause a man the trouble of having to look for a fresh job, besides proving that he is a B.F. (which stands for blithering fathead, and several other things).

Properly proportioned spanners and box spanners must be provided for the purpose. Tightening up of nuts with pliers and pincers damages the edges of the nuts

and generally spoils what might otherwise be good work.

The nuts will next have to be made secure, and the method which now seems to be most universally adopted is to file the bolt down if necessary, until about 1-16th full is left projecting beyond the nut, and then to rivet this carefully over, taking care to hold a suitable piece of iron or steel bar at the back of the head whilst it is done. This riveting can best be done with a small ball-headed hammer weighing about $\frac{1}{2}$ lb.

THE TOP HALF.

Having now completed the bottom portion of the rear end of the fuselage, it is necessary to commence on the top portion, which, being similar to the bottom, can be built in a similar manner, with the difference that as the lower portion is not parallel to the top longeron, the distances of the struts apart will be slightly longer in the low portion, and it will for this reason be necessary to refer to the plan and see if the existing jig can be utilised.

Otherwise a new jig will have to be prepared on similar lines.

Assuming that the top and bottom portions of the rear end of the fuselage have been built, the next question to consider is, how is the fuselage to be completed, with its side struts to put in, and all the swaged wires to be fixed and adjusted?

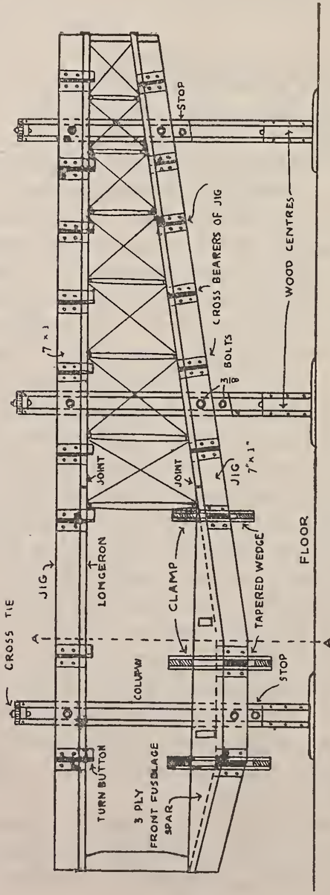
CHAPTER III

ERECTING THE FUSELAGE.

To enable this to be done easily it will be advisable to consider making a simple jig, which will ease the erection tremendously, and enable the work to proceed rapidly, and tend to prevent mistakes. For this purpose, make six portable columns standing on feet, with adjustable top and bottom cross rails and longitudinals (see Figs. 10 and 11). The use of this jig will enable work to be put in hand quickly, and when completed taken down. Reference to Fig 10 will give an idea of this construction.

Having completed the jig, the first thing to do will be to take the top rear portion of the fuselage and attach it to the top portion of the jig on the underside of the cross bearers as shown, and then put the bottom portion of the fuselage on the top of the lower cross bearers as shown. After which, level up the top portion of the jig with a spirit level, and then adjust the lower portion to the inclination given by the measurements of the lengths of the struts between the longerons.

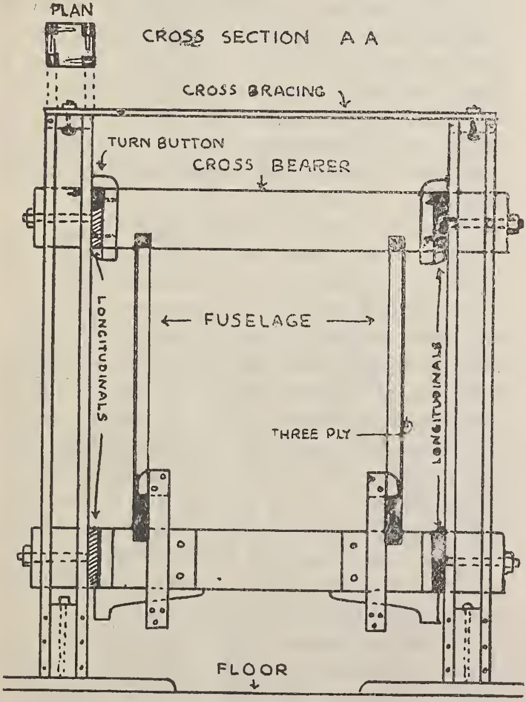
After this is done and carefully checked, the struts with their fittings on them may be put in their respective positions and



SECTIONAL ELEVATION OF JIG AND FUSELAGE

FIG. 10.

bolted to the longerons and riveted up, and the ash skid post fixed. Then the only work remaining to be done is to put



FRONT PORTION OF FUSELAGE JIG

FIG. 11.

in the tie rods and fork ends with lock nuts, and to adjust the tension on them.

Then the lower longitudinal and cross bearers can be lowered slightly, and any adjustment necessary in the tie rods will be at once seen while the rear portion of the fuselage is in suspension and the "line of flight" of the machine is in a true and horizontal position. In this manner the necessary trueing up for the fuselage can be done.

THE FRONT SECTION.

The front portions of the fuselage can now be constructed. They will have to be constructed in a jig similar in design to the rear portions, only these parts will be left- and right-handed, instead of top and bottom. Extreme accuracy will be necessary in all measurements, especially in the distance between the top longerons and the bottom ash spars, otherwise it will be impossible to join these front portions, when made, to the rear portions already finished, as the joint of the longerons is a plain butt-joint, with cover-plates of steel top and bottom, like fish-plates.

A jig will have to be made for the left hand and also the right hand, as the outsides are covered with three-ply wood, on one side only, namely, the outside, being attached to the longeron, engine bearers, cross bracing (which is of wood), and ash spars with small screws.

Assuming that the front portions of the fuselage are completed, and passed by the A.I.D. Inspector, they will be taken to the erecting shop. To put them in the jig, the bottom stop and the longitudinal sides of the jig may have to be lowered slightly to enable them to slide into the slots made to hold them in the cross bearers. After they are in position, the tapered wedges will be driven home. This will clamp them firmly to the bottom cross bearers (see Fig. 10), other adjustments being made that are necessary.

CHECKING FOR ALIGNMENT.

These having been completed, it will be necessary to try the whole jig with a spirit level, and some 22 gauge steel wire stretched along the top and bottom centres, between the longerons, from end to end. Test them both, for vertical alignment, about every 2 ft., by means of a plumb-bob line, from the top wire to the bottom wire, taking extreme care to see that the plumb line from the top wire touches the bottom wire at each point tried on the same side. This should be done in the presence of the foreman erector, unless two skilled mechanics are available.

This check will be of the utmost value, as it will immediately show up any twist or inaccuracy in the fuselage, which must at once be rectified, either by alteration

of the jig, or alteration of the tie rods, or both, as may be necessary. If the greatest possible attention is not paid to this work, the fuselage will be all of a twist, which will not do, as it will seriously affect the machine when in flight, as the tail plane will be out of the horizontal with the wings, and the fin and rudder will not be vertical, therefore the importance cannot be over-estimated.

BOLTING UP.

Having checked the fuselage, both rear and front portions, and found them correct, and the joints of the top and bottom longerons in perfect alignment, without any artificial means being used, the fittings for the joints may be placed in position, and the bolt-holes carefully marked off. The holes can then be drilled by means of an electric drill and jig, the greatest care and accuracy being required, to ensure the holes being drilled centrally and vertically through the longerons.

These being done, the fittings can be bolted in position, thus permanently tying the front and rear portions together.

THE NEXT STEP.

If the works manager, or the foreman of the erecting shop, approves of the job as so far completed, the transoms, or cross ties, the seat bearers and the tank bearers, must now be fitted in. But if the fuselage

is allowed to remain in the jig whilst this is done, it will delay progress with fuselage No. 2, and as this is not permissible, the fuselage must be very carefully removed from the jig and put on trestles which have been previously levelled up.

In putting in the tank bearers and seat bearers, etc., the tops and bottoms of the front end of the fuselage must be accurately clamped together, before removal from the jig, with a distance piece in between of the correct size to maintain the theoretical width, otherwise the tank and seat bearers will be incorrect.

These having been fitted, the two compression struts, onto which the wing spars butt, must now be put in position, not forgetting when doing so that two fittings, left and right hand, have to be fitted onto the bottom ash spars at the same time, and the bolt-holes very carefully marked off, and drilled. After which, the fittings and struts may be put into position and bolted and riveted up.

The flooring can now be fitted in. This will consist of $\frac{3}{8}$-in. spruce, suitably stiffened with longitudinal bearers, the flooring being put in across the machine and screwed down with brass screws.

THE LANDING CARRIAGE.

Having got so far, it will be as well to consider the landing chassis struts. These,

owing to their being splayed outwards, will have to have their ends cut to an angle, where they bed into the strut-fittings attached to the ash front spar. To carry out this work correctly a proper start must be made and the work carried out in a systematic and workmanlike manner.

The first thing to do is to find out the distance from the top longeron to the floor of the shop and allow an extra half-inch for clearance when the wheels are on the axle. Having found the distance from the plan, which we will assume to be about 6 ft. 6 in., place the fuselage on trestles and packing. This height can be measured by placing a straightedge on the top longeron and measuring down to the floor, taking care before doing so to see that the fuselage is level longitudinally and transversely at each end and in the middle.

Having done this, procure a straightedge about 7 to 8 ft. long, and lay it across the top of the fuselage on its edge, over the centre of the front chassis strut. After having marked the centre of length on it with a fine knife cut, and the extent of splay each side, which for our purpose we will call 6 ft. 9 in., which will be 3 ft. $4\frac{1}{2}$ in. each side of the centre mark, attach a plumb-bob to each of these points. Allow the plumb-bob to hang down, and mark the point indicated by the point of the plumb-bob on a nicely planed board which

has been screwed to a couple of short trestles or supports, carefully made to coincide with the theoretical bottom of the wooden strut, and levelled up with a spirit level.

Having done this, the erectors will have their top and bottom points to which to fit the strut, and this method will prevent any inaccuracy, as they can utilise the fixed bases in bevelling the strut ends time after time, thus enabling accurate results to be rapidly obtained. Having cut and fitted the top end of the front chassis struts to the top fittings, the struts can be taken out and the bottom junction fitting fitted, bevelled, and bolted onto the bottom of the front strut.

REAR CHASSIS STRUTS.

The next thing to do will be to fit the rear chassis struts, which are slightly more difficult, as they splay outwards and rake backwards and upwards. Thus there are two angles to contend with, and for this purpose the angle between the two struts should be carefully obtained from the drawing office if it is not clearly marked on the plan.

The angle should be set out on a setting-out table, and a few stops screwed on to the table, to contain the chassis struts in their theoretical position whilst the rear strut is being shaped and fitted to the

fitting. For this purpose the front strut should be clamped down on bearers, which are a sufficient height off the setting-out table to clear any projection of the junction fitting. This will enable the rear strut to be fitted up in an identical angle to the fitting which it will be in when permanently fitted and bolted to the fuselage.

Having bevelled and fitted the rear strut, and having had it checked by the works inspector and the A.I.D., and stamped, the final assembly can be commenced. After the position of each chassis strut and the fittings on the bottom have been checked, the bolt holes can be drilled in position without further taking down. The bolts can be put in and tightened up and riveted over, thus finishing the fitting up of the chassis, with the exception of putting in the axle and attaching the wheels.

The next thing to do will be to shape up the ash skid post, and fit the skid lever hinge fitting on, which, being more or less similar to bedding in the chassis strut fittings, will require no special remarks. This also applies to the four centre plane struts.

STREAMLINE FAIRING.

The streamline fairing on the top of the fuselage at the rear end, aft of the pilot's seat, can now be put in hand. This will consist of $\frac{3}{16}$-in. three-ply semi-circular uprights, the highest one being 9 in. high,

and the same width as the fuselage, notched out on the radius about 2-in. pitch with $\frac{3}{8}$ in. by $\frac{1}{2}$ in. deep notches to take the $\frac{3}{8}$ in. by $\frac{1}{2}$ in. spruce stringers which run longitudinally with the fuselage to support the fabric. There will be about 10 of these stringers and one extra heavy section on each side for attaching the whole of the fairing to the fuselage. The height of the semi-circular 3-ply uprights gradually diminishes towards the rear, until the tail plane leading edge is reached, where it dies out. The whole of the spruce stringers forming the skeleton framework of the fairing are covered with fabric, which will be doped when completed, and varnished.

The covering on the top of the fuselage in front of the pilot's seat will consist of 20-gauge aluminium sheet strengthened with ash bends underneath, attached to the fuselage and also to the aluminium sheet with brass screws. This will be dealt with later on when dealing with the manufacture of metal fittings and work.

CHAPTER IV

WING STRUCTURE.

Having dealt at some length with the construction of the fuselage and chassis, we may as well consider the construction of wings. As the machine is a biplane, there are two right-hand and two left-hand planes and one centre plane to make. For the purpose of maintaining continuous progress in construction, we may as well commence with the centre plane, as this must be fitted up before the wings can be assembled on the machine.

The first parts to produce will be the two compression struts which take the end thrust of the main upper wing or plane spars. These will be of carefully selected rift, or vertical grain, spruce of the best quality, the dimensions of each being about 3 ft. 2 in. by $3\frac{1}{2}$ in. by 2 in., lightened out on both sides on each side of the centre for about 8 in. This will leave the strut solid in the centre for about 6 in., the lightening being $\frac{11}{16}$ in. deep by $2\frac{3}{8}$ in. wide, the corners having about $\frac{3}{8}$ in. radius to prevent splitting and fracturing.

The most suitable timber having been selected, it will be taken to the circular

saw and cut down to 3 ft. 4 in. by $3\frac{5}{8}$ in. by $2\frac{1}{8}$ in. It is then advisable for the works inspector to see it. Assuming that he passes it, the next thing will be to put it through the planing machine, and reduce it to the correct size plus $\frac{1}{32}$ in. full over all to allow for shrinkage. It will then be sent to the wood setter-out, who will, after referring to the drawings, set out the four lightenings, which will have to be machined out on the spindle.

If the spindle hand does the work carefully and has his cutters properly sharpened, there will be no need to sandpaper out the lightenings when it comes from the spindle. This can be done, and is done in works where the spindle hand knows his job and is not driven at his work by someone in authority whose sole aim in life is output from the department, regardless of finish.

Such forcing the pace amounts to nothing less than scamping the work. It costs the firm pounds, and delays final production. To say the least, it should be severely dealt with, after a careful inquiry has been made of the spindle speed and the state of the cutters and the material they are made of. Also sandpapered work never has the same accuracy of finish as wholly machined work.

Having received the compression struts from the spindle, the next thing to do is to

find the centre of the solid part between the lightenings and then mark off the extreme ends of the struts, not forgetting the fact that an additional amount must be left on the ends of the struts to enable the ends to be accurately cut to suit the dihedral angle of the wings. This angle is the upward slant of the wings towards the tips, and may be described as the angular space included between two planes which meet each other.

FURTHER STEPS.

Having completed the machining of the struts, the wiring plates should be put in position, and the position of the bolts marked off. Then the holes should be drilled, so that when the compression ribs at each end and the intermediate ribs are in position, the wiring plates can be put on and bolted to the compression struts, and the swaged wires fixed, and the tension adjusted.

However, before this can be done, the outside box ribs or compression ribs, and the three ordinary centre ribs, must be made.

RIB MAKING.

To make the ribs correctly to the contour and dimensions shown on the plan, it will be best to set out one on a thin hard wood board, and then cut and finish the board accurately to the shape of the rib.

After which this template can be used to set out the jig board on which the ribs will be constructed and checked and finished. Ribs will be described later on.

To give an idea of the shape of the ribs which will be used in the construction of the wings and centre plane, we will assume that the length from the nose or leading edge to the trailing edge is 5 ft. 6 in. Therefore set out on the hard wood board, which will be the template of the rib, a straight line 5 ft. 6 in. long. This is called the chord line. The board should be not less than, say, 6 in. wide.

SETTING OUT WING CURVES.

The next thing to do is to produce the correct wing curves. On referring to the drawing we find that at about 6 in. from the left-hand end of the line a vertical offset of $\frac{1}{4}$ in. is given; therefore set up a fine line at right angles to the chord line across the board, and carefully cut in a mark $\frac{1}{4}$ in. above the chord line. This represents the curved line or underside of the rib at this point. Above this dimension is another, which we will say is $3\frac{1}{4}$ in., this representing the top curved line of the rib, and as we refer to the drawing, we find that in this manner a number of points in the top and bottom curved lines of the rib are thus given on the drawing, thus enabling the rib to be set out.

When all the points have been set out on the chord line and the vertical lines set up and the two points on each vertical line marked, all we have to do is to get two pieces of thin spruce about 6 ft. long by $\frac{3}{8}$in. wide by $\frac{3}{16}$ in., and tack them down to the board, so that one edge cuts all the points nearest the chord line, and the other the points at the top, farthest away from the chord line. The space enclosed thus is the true and required outline of the rib; that is, if the given offsets are correct, which they are not always, in which case the mean average must be taken.

Assuming that they are, and that the dimensions have been accurately set out, all we now have to do is to cut in a fine line with a knife, carefully following the curves of the laths nailed down, on the inside. The enclosed piece of hard wood will then be cut out on the band saw, and we must be careful to give instructions that all the points on the top and bottom curves are to be left in, so that they can be accurately worked down by the wood template maker. This gives the template maker sufficient latitude and material to ease off or soften any angular points in the curve which may arise.

After the template has been made it should be sent to the inspection department and carefully checked and then submitted to the A.I.D.

RIBS.

After it is passed and stamped it can be returned to the wood setter-out, who will mark off the spruce webs for the compression ribs of the centre planes, which can then be tacked together, four at a time, and sent to the band saw, where they can be sawn out to within about $\frac{1}{8}$ in. of the line. It is necessary for this amount to be left on by the band saw, otherwise the spindle may not be able to finish them off clean.

On coming from the band saw they will be tacked down to a template jig-board of hard wood, which is $\frac{1}{4}$ in. wider all round, to allow for the projection of the spindle-cutter, and sent to be spindled in a manner similar to the method adopted in spindling the fuselage struts.

THE RIB JIG.

After being spindled the webs will be sent into the wood parts department and

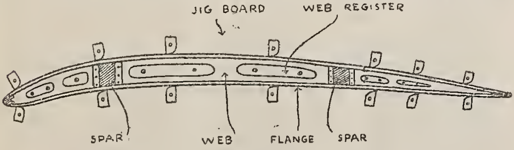


FIG. 12.

the jig-board obtained from the wood template maker (see Fig. 12). The jig-board

consists of a piece of hard wood such as beech, oak, or ash, about 1 in. thick, about 9 in. wide, and 6 ft. long. On this will be laid a piece of selected board, planed both sides, and cut to the exact contour of the ribs less $\frac{1}{4}$ in. on the top and bottom edges, the $\frac{1}{4}$ in. being made up by the flanges on the top and bottom of the ribs. This board, or packing as it really is, will in this case be about $1\frac{3}{8}$ in. thick, as the web may be assumed to be about $\frac{3}{8}$ in. thick, with lightening holes in the centre and ends. The flanges we may assume to be about $1\frac{3}{4}$ in. wide. The $1\frac{3}{8}$ in. packing will now be carefully glued and screwed onto the centre of the 6 ft. by 9 in. board, and on the top of this two short pieces representing the section of the spars will be carefully and accurately fixed in position. These pieces of wood are for the purpose of accurately locating the position of the web on the jig and checking the holes, which are cut out to allow the spars to pass through. Having got so far, it will now be necessary to fix turn-buttons to the jig-board so that when the flange is bent to the curve of the rib, preparatory to being glued and screwed to the web, it may be accurately and permanently retained in this position until the rib maker has had time to put in the screws.

The next thing to do will be to cut two $\frac{5}{16}$ in. slots right through the $1\frac{3}{8}$ in. packing on the jig-board. These two slots

are the locating positions of the two small vertical stiffeners, to strengthen the web and prevent buckling under load. The slots take the vertical stiffeners and hold them in position whilst the rib is being constructed.

MAKING UP RIBS.

The rib-jig having now been constructed, the best thing to do is to make up one or two sample ribs, which must be submitted to the inspection department, and if found correct sent to the A.I.D. for final inspection and approval. After which the construction of the required number can be tackled.

The method of procedure will be as follows:—Take two rib-stiffeners and place them in the slots made for them in the packing-board of the jig. Then take a web and lay it over the spar sections to locate it. After having glued the edge of the web-stiffeners next the web, fix the screws into these. Then take the top flange and slip it in between the web-edge and the turn-buttons, carefully cover with glue the edge of the web, then press the flange up to it and fix in position by turning the turn-buttons. Then with a suitable sized brad-awl make the screw holes in the flange, about 4-in. pitch, and screw the screws in.

SOME POINTS TO NOTE.

Don't hammer screws in, as is done in

many box and packing-case factories, for it is as well to remember that something is being made on which lives depend. Which, though it may not interest you, does interest the relatives of pilots.

Also it is best to see that the screws are put in straight, and at right-angles to the flange through which they are passing, especially if the screw selected is only just long enough for its job.

Also sharp screw-heads do not look nice when sticking up at all angles, and if you take the trouble to file them off, it, of course, weakens the heads, and possibly makes it impossible to remove the screw if it is at any time necessary, as in the case of repairs.

Generally speaking, it shows that you are not up to the standard of work required in aeroplane construction.

FINISHING OFF.

Having properly put the screws in just slightly below the surface, the bottom flange may now be fixed in precisely the same manner. The rib can now be left for half an hour, if another jig is available, for the glue to set. At the end of this time the rib is ready for finishing off, sand-papering, etc ; this work, of course, being done by unskilled labour, and on a sand-papering machine covered with garnet paper.

ORDINARY RIBS.

The next ribs to put in hand will be the centre ribs, three in number. These will have precisely the same contour or curves, and, therefore, the rib template will be required again. But another jig-board must be prepared. This will be done in the same way, only as the web is only $\frac{5}{32}$ in. three ply, and the flanges about $\frac{1}{2}$ in. by $\frac{3}{16}$ in., with a $\frac{1}{16}$ in. deep groove in the centre of one side to take the $\frac{5}{32}$ in. three-ply, the packing piece on the rib jig-board will have to be reduced in thickness. This will allow the edge of the $\frac{1}{2}$ in. flange to lie level on the jig-board and will ensure the flange being central with the web. To this it will be attached with 20 gauge by $\frac{1}{2}$ in. long gimp-pins, and glued. The webs will, of course, have to be carefully set out as they are lightened in the centre, and have also to have the holes cut in for the spars to pass through. Otherwise these ribs will be constructed in the same way as the end ribs.

THE LEADING EDGE.

The next thing to put in hand will be the leading and trailing edges, which will be of spruce with ash tips, V-shaped, with a $\frac{3}{8}$ in. radius at the small end of the V, and lightened out at the mouth of the V about $\frac{3}{8}$ in. deep, allowing $\frac{3}{16}$ in. thickness either side. The rectangular section of the spruce

and ash required will be about $1\frac{1}{8}$ in. by 1 in., to allow for cleaning up about $\frac{1}{32}$-in. full and shrinkage.

The first thing to do will be to plane up a sufficient length of spruce and ash to this size and then spindle out the lightening, after which it may be cut in the spindle to its finished shape (see Fig. 13), leaving about 6 in. solid each end for additional stiffness.

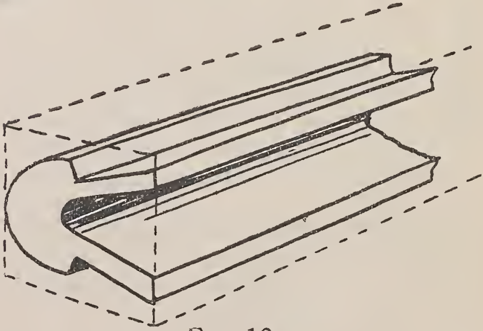
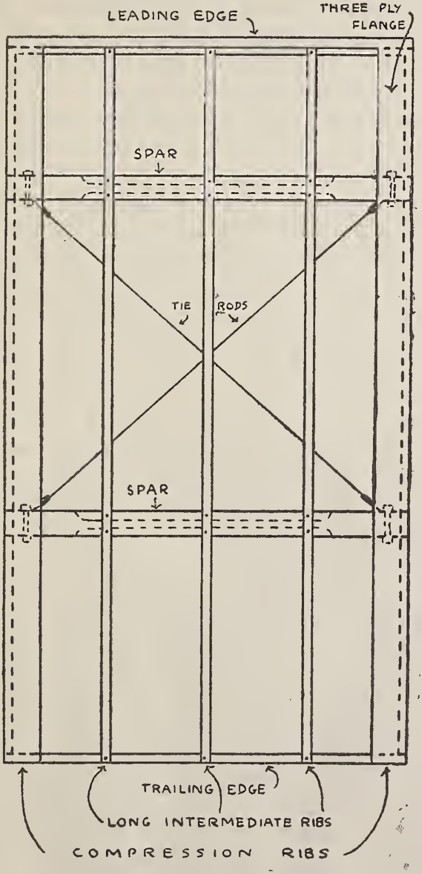


FIG. 13.

A PLANE ERECTING JIG.

Having considered the manufacture of all the parts required to construct the centre plane, the next thing will be to erect it. A completed Centre Plane Section is shown in Fig. 14. As very considerable accuracy and squareness is required, it will be necessary to do this work also in a jig, as these centre sections must



PLAN OF CENTRE SECTION

FIG. 14.

be absolutely interchangeable with each other, and square. Therefore, a small jig-table must be prepared in a manner similar to the fuselage jig-tables.

On this set out a centre line lengthways of the table, and on this line, at right-angles to it, set out the centre line of the compression spars. Then carefully with a gauge mark the centre line on the ends of each spar when it is standing on one of its narrow sides. Lay the spar on the jig-board and see that the centre lines on the spar and jig-board coincide exactly. Then clamp them down, and screw hard wood stops on each side to keep them there, taking care not to put the stops in the way of ribs. Also fix end stops to locate the compression spars in the centre. Then very carefully check the measurements in between after having completed the stops for holding the spars.

The next thing to do is to glue and screw four pieces of packing under them, namely, two near each end to raise them up off the jig about $\frac{1}{4}$ in. This is necessary to enable the bottom flange of the rib to slide into its position on the spar. To prevent the ribs from being pushed on too far, or being out of parallel with the centre line, limit stops must be fixed, so that the ribs can only be pushed on to the spars a definite distance, with absolute accuracy. Turn-buttons with a fairly long sweep must be

fixed to keep the outside ribs up to this position.

Having done this, the next thing to do will be accurately to locate the three light centre ribs, and fix stops each side of them to hold them in position on the spars, for fixing. If all these things are done it will be impossible to build the centre plane incorrectly, provided the stops have been accurately placed in position, and the ribs and spars made correctly.

All that now remains is to get the jig passed by the inspection department, and assembling can then be commenced.

ASSEMBLING.

The first thing to do is to mark off the bolt holes on the spars for the wiring plates and strut eyebolts and get them drilled, preferably on a drilling machine. This being done, slide on the three light centre ribs, then bolt on the wiring plates to the spars, and attach the swaged wires to them, at one end only; then slide on the compression end ribs.

Then place the whole over the jig and adjust each component part and drop the lot into their respective positions in the jig. Screw each in position, and give a touch of glue to each one, then leave the whole to set.

When the glue is set the centre plane can be taken out, the leading and trailing edges

fitted, the bracing wires coupled up, the tension adjusted, and the whole plane finished and sand-papered off, ready for covering with fabric, with the exception of fixing the four eyebolts for attaching the plane to the vertical centre plane struts.

BOTTOM MAIN PLANES.

The construction of the bottom main planes must now be considered, and the first thing that has to be done is to produce the front and rear spars, which we will assume to be 19 ft. 9 in. and 19 ft. 3 in. long, respectively, by $3\frac{1}{2}$ in. by 2 in., tapered at the outer ends and lightened in the web where possible to H or girder section.

First-class spruce must be selected, and the timber cut so that a vertical grain is obtained when the spars are finished and lying in their natural position, the minimum number of vertical grains per inch being not less than 6 per inch of width. They must have no short or twisted grain, and must be free from any faults such as "feathers" in the grain, sap, dead wood, shakes, splits, knots, or pockets of resin, however small.

As the A.I.D. may be relied upon to give these a severe testing and a rigid inspection, it is not advisable to cut up faulty timber and work it up in the hope of getting it passed.

Having selected the timber, it will be

marked off, and taken to the circular-saw and sawn into the required rectangular section and length plus about 9 in. for cutting and finishing off ends.

These sides will be planed and the edges shot; they will then be sent to the setter-out, who will set out the lightenings on a template of the length and width of the spar, but $\frac{1}{2}$ in. or $\frac{5}{8}$ in. thick, preferably of hard wood. The outer end will be tapered to suit the diminishing depth required in finishing off the tip of the wing where it cuts the leading edge.

MACHINING OUT.

The lightenings having been marked off on the actual spar, a template or section of the finished spar, where the lightenings occur, should be made and sent in to the mill to the spindle hand, who will prepare the cutters, and spindle out a short length of spar to test the dimensions of the cut. This being correct, the spars may be lightened out as far as the straight portions go.

After which the spar template must be placed on the spar and the curved portion carefully marked off. Then the spar must be sent to the band saw to have this portion cut to the curve, and it can then be finished off on the spindle or bench, as may be more convenient, or sent to the wood-finishers' benches.

It will then be ready for the spindling out of the lightening to be completed, as in Fig. 15.

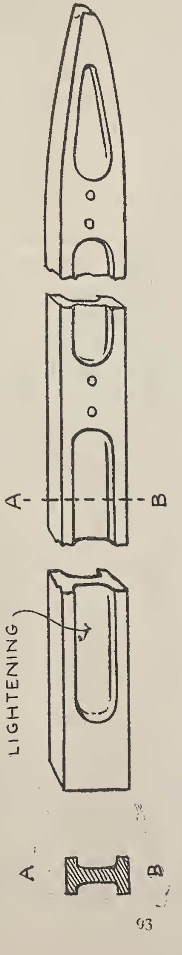
BEVELLING OFF.

The last operations to be done to complete the spars for use will be to bevel the edges slightly right across to fit the contour of the ribs. As this bevel will be a definite angle and will probably be specified in degrees and half degrees, a bevel protractor will be required to set out and check this operation. Careful reference to the plan should be made to ascertain the amount of bevel required. This work may either be done on the planing machine or the spindle.

A DELICATE OPERATION.

The bolt holes for the wiring plates must now be marked off, also the holes for the strut eyebolts, which go vertically through the spars.

Before drilling these bolt holes it is necessary to point out to all concerned, that the importance of these holes being drilled perfectly cannot be over-estimated, and unfortunately, there are many who, being new to aircraft work, get an idea that the works manager, foreman, or inspectors, who point this out, do so either for the sake of talking or of showing their authority. This is not so. The holes must be drilled out in one dead straight line, and not



LIGHTENING IN SPARS

Fig. 15.

started from each end, and allowed to meet "somewhere" in the middle, nor as is done occasionally, may an old bolt be driven through to clear the hole. This sort of work is not wanted, neither are "rat holes."

The holes must be accurately bored or drilled with a sharp cutting tool, exactly where they are required, and no limits are allowed for deviation, therefore it is advisable for all bolt holes to be bored by an accurately running sensitive drilling machine, bolted down to a firm foundation. Accurate work is not to be obtained from machinery attached to wooden floors in galleries, as is found in some works.

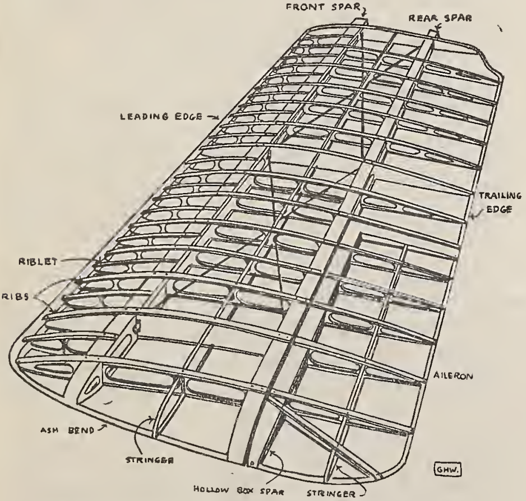
FINISHING THE SPAR.

Having completed the holes, the last work to be done is to taper the end of the spar down to the point where it meets the leading edge, and this will be done by the wood-finishers' department, before going to the erecting shop. This being done, it can now be inspected and passed by the A.I.D.

WING SECTION ON TRESTLES.

The construction of the wings may now be considered, as the manufacture of ribs has been previously dealt with, and also the leading and trailing edges. For this work some light trestles, three in number, will have to be made, about 3 ft. high and

3 ft. 6 in. wide, of 1 in. boards, on edge, screwed to the floor with light iron knees and braced together with a light longitudinal bracing about $3\frac{1}{2}$ in. by 1 in. Inclined bracing will connect the longitudinal bracing to the vertical leg of the middle



SKETCH SHOWING WING CONSTRUCTION.

FIG. 16.

trestle. The trestles being completed the erection of the wings can be commenced.

Take the spars and lay them in their correct positions on the trestles and mark off the positions of the various ribs, of

which there will be about four different types. Commencing from the root of the wing and working outwards to the tips, we shall have the following: first, an extra strong rib with a solid web, then a number of ribs of a light design, with three-ply or lightened spruce webs, and then another rib with a solid web, where the joint occurs between the rib and the aileron.

After this, we have a number of ribs with the trailing end cut off where the rib flange reaches the rear side of the rear spar. The aileron makes up this portion, and is attached to the rear wing spar by about four hinges, which are attached to the wing spar and the aileron spar by bolts.

As each type of rib has a drawing number and part number, it will save a lot of confusion if the position of each rib on the spar has the drawing number and part number stamped on it with a rubber stamp, as this will enable any unskilled labour which may be employed in the erecting shop to place the right type of rib in the right place, and prevent mistakes and disputes.

Having marked off the positions of the ribs, the next thing to do is, make a list of the ribs required, and the number of each type required, and obtain these from the finished wood parts stores, and examine each one to see that it has been inspected and stamped by the A.I.D. It will be as

well to keep the list of ribs for future use.

We can now thread the ribs carefully on the spars. In some cases we shall, no doubt, find that the spar holes in the webs of the ribs require easing. This can be done with some sandpaper wrapped round a stick.

The first ribs to be put in, will be the ribs in the centre of the wing. Then work outwards towards each end. Having threaded all the ribs on the spars the front spar should be clamped down to the trestles, and the mark of the rear spar end carefully squared off with the end of the front spar. These ends refer to the root of the wing, next to the fuselage.

This being done the ribs can be fixed to the spars by means of small brass screws. Each of the ribs should be tested with a square to make sure they are square with the spars.

WIRING UP.

The ribs being fixed, the wiring plates can be bolted in position and two or three bays of wire bracing put in, to keep the wing in shape.

It will be as well now to thread the stringers in position. These consist of long lengths of spruce about $\frac{5}{16}$ in. square, which run parallel to the spars, and pass through the webs of each rib just under the rib flanges.

We can now turn our attention to the

leading edge, which consists of spruce lightened out to the shape shown in Fig. 12. This will be now threaded through the noses of the ribs, care being taken, after it is in position, to remember to see that all ribs remain square with the spars. As soon as this is done, the ribs can be screwed to the leading edge, and each side of the rib, then touched with glue.

SCARFING THE WING TIP.

The next thing to do will be to prepare the scarfed joint for the junction of the leading edge with the ash bend at the tip, this will be done by tapering the end off for about 7 in., after which the bend can be treated in the same way, carefully fitted and tried in position. Then the permanent joint with glue and $\frac{3}{4}$ in. by No. 6 gauge brass screws can be made. Two screws to each side should be sufficient, the whole being clamped up and left for about 10 hours. After that the scarfed joint can be shaped up and cleaned off, and left ready for binding with balloon cord knotted at each turn.

THE TRAILING EDGE.

The next thing to do is to fit the spruce trailing edge, and this will be done in the same way, but without any binding cord or similar joint. The strut to the end compression rib can now be fitted, also the

small packing pieces between the ribs and riblets (small ribs), which are glued and tacked down. In some wings this is left out.

FINISHING OFF.

When the whole lot is done, the next thing to do is to go over the whole skeleton wing and chisel off all sharp points and square corners and file off all projecting or rough screw-heads, tacks, and wood ends of riblets, etc., etc., and well sandpaper all over. After this, the wing may be considered ready for final trueing up and passing by the works inspector, who, if he finds any faulty work, should see it rectified. Thereafter the wing is ready for passing by the A.I.D., for tapeing and varnishing.

Then it will again be inspected by the A.I.D., and covering may be commenced.

CHAPTER V

WING COVERING

The cover having previously been stitched up, and all seams carefully examined, and the cover being quite dry, it will be drawn onto the plane, starting from the leading edge and pulling across to the trailing edge, half the cover being on the lower side of the plane, and the other half on the top side. The fabric will then be carefully and evenly pulled taut, and tacked down temporarily, all seams being carefully straightened by pulling the fabric at each end. After this, all surplus fabric will be cut off and the two ends of the fabric sewn up, taking care to turn in the edges of the fabric, the joint being along the centre of the trailing edge, and, where the aileron gap occurs, along the top edge of the rear spar.

STRINGING.

Having neatly sewn up all the edges, the next operation is stringing the wing to keep the fabric tight to the ribs. This is done with a light, fine string, which is passed through the fabric from the top to the bottom round each rib about every four

inches and knotted at each turn, taking care to knot up fairly tight.

This work, as well as the sewing, will be done by girls, and they do it well, after having a little tuition, but they always need a little supervision. One thing to be avoided is making holes with the stringing needle where it is not intended a string should pass through, the only hole permissible being the one where the string passes through.

When this is done, the plane should be weighed to see that it does not exceed the standard weight for its type, and is then ready for its first coat of dope.

CHAPTER VI

DOPING.

The plane having been brought into the dope room, one thing to do is to see that the specified temperature demanded of the room exists. The plane is then laid on bearers running longitudinally under the spars, and these will be supported on trestles. The dope then can be put into galvanised paint pots, for convenience. Special brushes will be required for doping, preferably about 4 in. wide. Common brushes for this work are useless, as the hairs come out and cover the plane, and spoil the finished appearance.

To start doping take a fair amount of dope on the brush, and work it first from leading edge to trailing edge, and then from left to right. Spread it evenly, taking care not to start too big a patch at once. In this manner cover the whole plane, after which the specified time must be allowed to elapse before proceeding.

STRIPPING.

The next thing to do is "stripping" the plane. This consists of again doping the line of stringing, and at once laying a strip of frayed tape over the stringing onto the

wet dope and finishing off smooth with the brush. It is well also to cover the edges in a similar manner.

Allow the whole thing proper time to dry, according to the doping scheme employed. When dry, the whole should be doped again, until it has had about four or five coats. When this is done, the identification mark is set out, and the outer circle filled in with blue dope or colour, and then the red bull's eye. After this is done on the undersides of the lower planes, and has dried thoroughly, the wing can be varnished with the special varnish.

When this has set, the coat of pigment can be put on the top, and, finally, the last coat. The plane can then be left to dry, the whole of the doping process being complete.

In this manner ailerons, tail planes, and elevators will be doped. Other schemes are available, and may be worth trying.

CHAPTER VII

AILERON CONSTRUCTION.

The construction of the ailerons can next be taken in hand, for the work of construction is very similar to wings. The difference is that the spar of an aileron is frequently hollow, and made in two pieces, very carefully and well glued together.

The making of this hollow box spar requires very careful consideration, unless undertaken by experienced hands who are used to this class of work.

The timber selected requires to be of the best quality, and straight grained and dry, otherwise failure may reasonably be expected, and a considerable amount of time and material will then be wasted.

The aileron spar we may assume to be about 4 ft. 9 in. long and $2\frac{1}{2}$ in. deep and about $1\frac{3}{4}$ in. broad. They are made in halves, with about six lightenings in each half opposite each other. These will be cut out on the spindle.

These two parts form the spar, the lightenings being in the middle. The whole, when together, will taper down in the last third of its whole length to about one half of its normal sectional area, the ends of the spar, of course, being left solid.

In preparing these two halves to form the spar a considerable margin of timber should be allowed for cleaning up on the outside after spindling out the lightenings. Also, it is most essential that the halves of the spar, after coming from the spindle, should be placed in clamps to dry, as this timber, being freshly cut out, is likely to twist or warp and lose its shape through exposure to the air if left to dry in a free state.

The halves of the spar having had a couple of days to dry, should now be brought to the wood-finishers' benches, where the joint faces will have to be carefully tried for truth of surface, and all inequalities removed with a trying plane, so as to remove as little as possible.

Having made the joints true, the next question is glueing the two halves together. For this purpose, glue of special strength will have previously been obtained.

Before spreading the glue, the surfaces of the two halves of the spar are frequently ironed with a hot iron, so as not to let the glue grow cold and partially set before the two halves can be placed together.

Great care indeed must be taken to spread the glue quickly and very evenly. This should be done with a brush of moderate size and good quality. After this, the two surfaces should be slightly rubbed together and quickly and evenly clamped

up and left to dry in a temperature of about 65 deg. for a couple of days.

The spars having thoroughly dried, can now be taken out of the clamps and sent to the wood-finishers, who will dress off the outside of the spar to the finished dimensions, taking considerable care to leave the spar all over a bare $\frac{1}{32}$ in. full.

The spar can now have the holes for the hinge bolts and fittings marked off and the holes drilled on the drilling machine.

MAKING THE AILERONS.

The spar can now be sent to the Works Inspection Department, and, if passed, sent to the A.I.D. Inspector for final inspection, and then sent to the finished parts stores, ready for issue to the erectors.

The ribs for the aileron will be constructed in jigs similar to the rear portions of the ordinary long wing rib jigs, previously described and illustrated, as the aileron forms a part of the outer end of the wing, and is of the same contour and streamline section. About six ribs will be required, including the outer tip rib, which will be of slightly different construction from the rest, being made with $\frac{1}{8}$-in. three-ply web.

THE TRAILING EDGE.

The trailing edge consists of an ash bend terminating in a long straight portion

which forms the whole of the trailing edge of the aileron, the width being about 1 in., of tapering cross section, which is about $\frac{3}{8}$ in. thick at the leading edge side, and tapering to the trailing edge to $\frac{1}{4}$ in. thick, this being rounded on the edge, these being the finished dimensions.

Unless the firm carrying out contracts involving steam-bending are used to doing this sort of work it is best to obtain the bends from firms who specialise in this class of work.

In ordering up the required ash bends, we should have to specify that the ash bends be made out of $1\frac{1}{4}$ in. by $\frac{5}{8}$ in. ash. This size will allow of all imperfections being machined out, when being machined up on the spindle.

A surplus of about 15 per cent. should be allowed for breakages, bad wood, bad bends, etc.

MACHINING BENDS.

Having received the ash bends from the steam-benders, they can be taken from stores and passed into the wood machining department. The next thing to do will be to get the cutters for the vertical spindle made, together with the metal gauge of the section; these having been passed by the Inspectors, the work can be proceeded with.

This will be done by passing the bends

past the cutter, in a manner similar to that used when spindling the leading edge of the wing.

The trailing edges of the ailerons when finished will then be examined by the Inspectors, and stamped by the A.I.D., if passed.

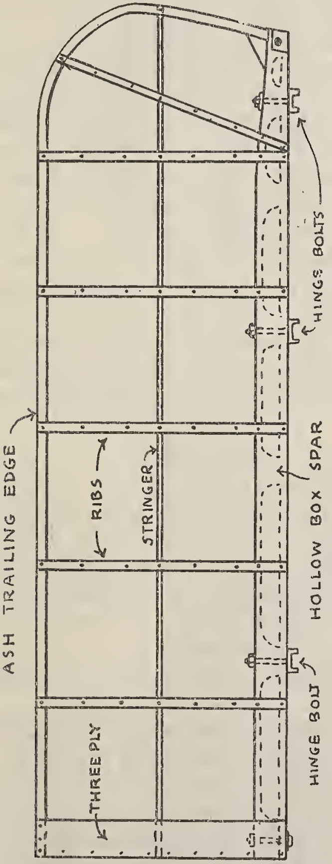
ASSEMBLING THE AILERON.

The first thing to do now will be to assemble the aileron. To do this it will be best, if many are to be made, to make a couple of jig tables, left and right-hand, similar to those used for the fuselage erection. This table will be made, and cramped together, out of 6 in. by 1 in. flooring, covered with about $\frac{1}{4}$ in. three-ply sheets.

The spar can be laid on this jig table, and the necessary stops glued and screwed around it to keep it in position, taking care to miss the position of the ribs. The ribs can now be put on to the spar and squared up carefully, this being of considerable importance, after which they can be glued and screwed into their final position.

The ribs are held in their place square to the spar, and prevented from moving, by additional stops at the trailing end of the ribs, and also at their end next to the spar, thus ensuring their being square with the spar.

The trailing edge can now be threaded through the ends of the ribs, and the



PLAN OF AN AILERON

Fig. 17.

curved end of the ash bend attached and jointed to the spar. This should be done first, in case the joining affects the radius of the curve. This procedure allows of any necessary adjustment being made

The next thing to do now is to complete the fixing of the ribs, this being done by the usual method of glueing and screwing. After this, the flanges can have their surplus ends cut off and rounded. The last part to be fixed is the spruce stay from the spar to the end rib, at the opposite end of the ash bend. (See Fig. 17.)

The aileron can now be inspected, and if passed by the Works Inspector, can be inspected by the A.I.D. and passed—with luck.

FINISHING.

The skeleton aileron is now ready for painting and varnishing, after which the hinge fitting can be attached, when the varnish is dry. It can then be inspected, and is ready for going to the covering shop to have the fabric put on and stitched up, exactly as in the wings.

The doping and varnishing only remains to be done.

The next thing to be constructed will be the tail-plane, elevators, the fin, and rudder; as they are constructed principally of metal, they will be constructed in the metal department, and to this department we shall now have to turn our attention.

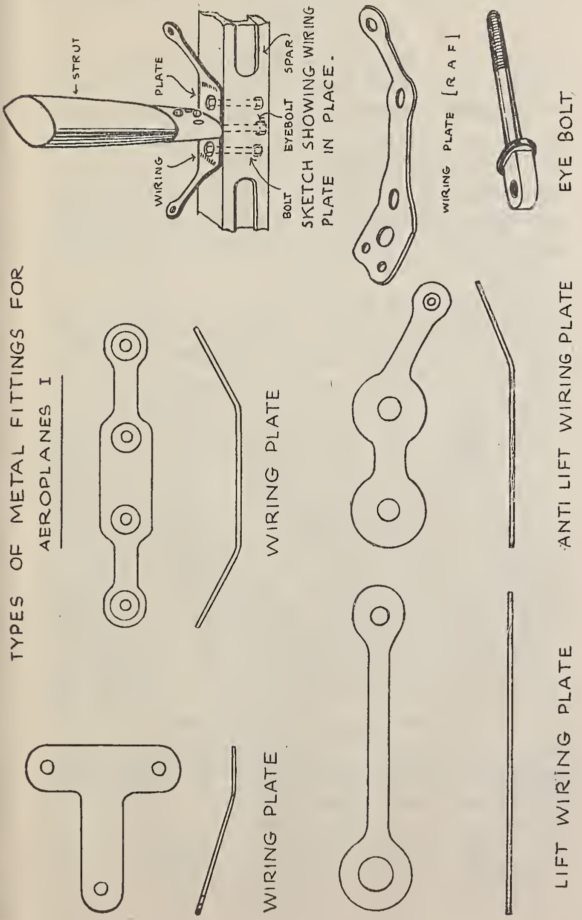

TYPES OF METAL FITTINGS FOR
AEROPLANES I
STRUT
PLATE
WIRING
BOLT
EYEBOLT
SPAR
SKETCH SHOWING WIRING
PLATE IN PLACE.
WIRING PLATE [R A F]
EYE BOLT
WIRING PLATE
WIRING PLATE
LIFT WIRING PLATE
ANTI LIFT WIRING PLATE

Fig. 18.

A RETROSPECT.

We will, however, for a few minutes, retrace our work back to the fuselage, with which we commenced. The wood work is all completed, and the process of assembling with fittings which we had not made has all been dealt with, and it is now necessary for us to consider the various methods of making a few of the required fittings.

On referring to Fig. 8, we see from the drawing that 12 strut fittings are required. In the fuselage, these consist of wiring plates, with a square steel shoe welded on, which takes the strut end. These fittings are simple, but require considerable care in making, as aeroplane parts consist usually of light designs with small factors of safety. Which means that what is made must without doubt be made from material strictly in accordance with the specification, and absolutely not under the sizes and dimensions shown on the drawings.

The slightest disregard of this will render all parts scrap; scrap means waste of labour and money, so don't forget this, it may save time. It is useless to try substitutes. Go for absolutely the right thing first time, and have it.

CHAPTER VIII

THE MANUFACTURE OF METAL FITTINGS.

As we have only a small order with which to deal, it will be useless to consider, at this stage, the production and use of punches and dies for the production of these parts, as the quantity is insufficient.

The die and punch would cost almost more than the fittings, and probably take longer to make than making all the fittings more or less by hand. When I say by hand, I mean by sawing out on the metal jig-saw and filing up to a scriber line or a template, whichever method is adopted. The template, which is case-hardened, is no doubt safer, but it involves time in making templates which could be more usefully employed in this case on actual production, namely, all hands being employed on filing up wiring plates to a scriber line, and finishing off with a fine smooth file, preferably by the most skilled hands.

WIRING PLATES.

Having considered the three methods of production, namely, stampings; rough cutting-out, and filing up to a case-hardened template; or filing up a rough cutting to an accurate scriber line, I propose

in this case to use the last, as speed is everything in our days. Therefore, I propose to detail the organisation and operations of producing the wiring plates and similar parts by this method.

We should now refer to the general arrangement drawing of the fuselage, and from the particulars given thereon ascertain the drawing and part number of each fitting, and obtain the necessary drawings. They will be sent to the planning department, who will examine the drawing, and ascertain its particulars, such as the material required.

In this case it will be mild sheet steel, to the specification mentioned in the schedule, and passed by the A.I.D.

The planning department will also detail, on the instruction card to be sent into the works, the best way of producing the fittings and the sequence of operations, and full particulars of the gauge, etc., to be used. They should also, before issuing the instruction card to the works, ascertain if the material is available in the stores.

If it is, then they will fill in and issue to the stores a material requisition for the amount of the metal required to complete the fittings and the parts, as ordered for the first batch.

Having done this, the order goes to the foreman of the metal shop, and the metal is also sent from the stores to the metal shop.

The metal, together with the job and instruction card and the blue print, having been received, the foreman will then give the blue print to the setter-out, together with the instruction card.

The setter-out will then take a piece of thin metal, and set out the wiring plate. This will, on completion, be sent to the inspection department to have the setting-out checked with the drawing. It can then, if passed, be sent to the template maker, who will produce one setting-out template.

When this is done the template will be sent to the inspection department. If correct, it can then be sent for the final inspection to the A.I.D.

When this is passed, the marker-off will mark out on the sheet steel to be used a number of the parts as specified on the job and instruction card. This sheet of steel will then be handed to the operator on the metal jig-saw, who should at once proceed to saw out the parts set out on the sheet of steel, as closely to the outside of the scriber lines as is possible, but taking care at all times to leave the line visible.

MANUAL WORK.

As soon as some of these parts are roughly cut out, certain of the bench hands should at once be detailed to commence finishing these off, and as the remainder of

the batch come from the metal jig-saw, they also should, if possible, be distributed amongst further workers.

In the mean time, any drilling jigs needed will have been made.

By this means a large number of components can be quickly put through the works, and passed to the inspection department, who, if they find them correct, will pass them into the finished part stores. In this manner all parts required by the erectors can be made; and, if the progress department see that the right proportion of parts of various kinds required are made each day, there should be perfect progress. If there is not, the progress department should adjust and alter the numbers of parts demanded from the metal department, or the number of hands employed on any special kind should either be increased or decreased.

DRILLING PLATES.

The wiring plates having been filed up to shape and finished, the next thing will be the drilling of the holes at each end to take the A.G.S. pins of the fork ends, which are screwed onto the tie rods.

The necessity for these being perfectly drilled in their correct position, and absolutely at right angles through the wiring plates, renders it necessary to construct a drilling jig, in which one or two wiring

plates may be drilled at one time, according to the design of the jig.

A DRILLING JIG.

An easy way of making a jig is first of all for the expert setter-out to mark off the holes on a perfect wiring plate with the greatest possible care. He should use a sharply pointed fine centre-punch, and "centre pop" the centres of all holes required with absolute accuracy, especially taking care to hold the centre-punch vertically over the position of the hole which it is intended to drill, as if this is not done it will be found that the holes when drilled are not accurate, and just a couple of hundredths out of their correct theoretical position. Therefore give this simple matter the attention it richly deseres, as if this is not done it gives the small twist drill a lead off in the wrong direction.

Having done this, take a pair of fine spring dividers and set out the outside diameter of the hole, just a shade larger than the true size, so that when commencing to drill the hole, before allowing the drill to cut its full diameter cut, it will be possible on examination to satisfy yourself that the hole when drilled will be truly concentric with the small circle made by the spring dividers. If it is not concentric, alter it, or, as it is known in drillers' language, "draw the hole," to its correct position. This is done by means of a small,

accurately ground, diamond-pointed chisel, cutting a small chip out of the side to which it is intended, or necessary, to draw the hole.

PREPARING THE JIG.

Assuming that we have drilled the wiring plate with a $\frac{3}{32}$-in. drill in all holes, irrespective of their final required size, this operation only being done for the purpose of assisting us to produce an accurate drilling jig, take the wiring plate and lay it on a piece of $\frac{3}{8}$-in. or $\frac{1}{2}$-in. thick steel plate, say in this case about 6 in. by $3\frac{1}{2}$ in., previously carefully levelled by shaping up each face parallel to the other, and locate the wiring plate in the centre as near as possible. This plate will ultimately become the jig. Clamp it there, and accurately mark the holes off the wiring plate onto the jig-plate.

Having done this, unclamp the wiring plate, and with the spring dividers set out a $\frac{1}{8}$ in. circle round each centre-pop so that when you commence drilling you can see that the drilling is going to be accurate.

The $\frac{3}{32}$-in. holes having been drilled in the $\frac{3}{8}$ in. steel plate, take the wiring plate and lay it again on the steel plate, and either rivet it in position, with a rivet at each end, and if possible one in the middle, or bolt it on. This being done, the jig-maker can fit a semi-circular piece of steel, $\frac{1}{4}$ in. thick, round each end of

the wiring plate lugs, to keep it in position, leaving each piece big enough to be drilled and riveted in position.

These pieces having been fitted, the next thing to do is to fit a $\frac{1}{4}$ in. piece, or strip, of steel to each side of the wiring plate, and when accurately fitted, rivet them to the $\frac{3}{8}$ in. steel plate. The four pieces thus fitted form a bed for the wiring plates to be dropped into, say, two of them, or any other number according to the gauge of the steel.

This work having been completed, remove the temporary rivets from the wiring plate, and enlarge the holes previously occupied by the $\frac{3}{32}$ in. rivets, in the steel plate and the other holes, to a size equal to about $\frac{3}{16}$ in. bigger in diameter than the required size specified on the drawing.

This is done to enable the hardened steel drill guides, or bushes, to be fitted into the holes drilled in the $\frac{3}{8}$ in. steel plate. These are necessary because an ordinary hole is liable to wear out of shape, and cause inaccurate drillings, and, as these bushes are removable, they can always be replaced with new ones when worn.

MAKING DRILL BUSHES.

The hardened steel bushes should be made to the following dimensions. Assuming the diameter of the hole in each end

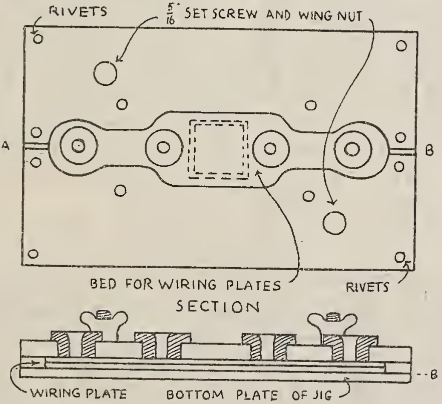
of the wiring plate lugs is $\frac{3}{16}$ in., it follows that a $\frac{3}{16}$ in. twist drill will be used. Therefore the hole in the hardened steel bush will be drilled $\frac{3}{16}$ in. The depth of the bush should be about equal to five diameters of the drill, which means in this case $\frac{15}{16}$ in. The walls of the bush may be, say, $\frac{1}{8}$ in. thick each side plus $\frac{3}{16}$ in. hole.

The total diameter of the bush will, therefore, equal $\frac{7}{16}$ in., the length being equal to the thickness of the jig plate, namely, $\frac{3}{8}$ in., and finishing up with a square shoulder, say, of $\frac{1}{8}$ in. wide, making the total diameter of the bush about $\frac{11}{16}$ in., with the entrance to the $\frac{3}{16}$ in. hole nicely rounded.

These bushes will be a pressing fit into the holes in the $\frac{3}{8}$ in. plate.

Having fitted similar bushes to all holes in the jig plate, the next thing will be to make a cover plate over the bottom of the jig to keep in the wiring plates tightly whilst they are being drilled. For this purpose we can use a piece of plate about $\frac{1}{4}$ in. thick, fitted with two hinged bolts and wing nuts, which fit into slots in the upper plate. This allows the wiring plates to be drilled in this jig being tightly clamped up to the underside of the drilling jig plate, accurately in position. Having fitted this plate the jig can be tested, and if found correct, can be put into general use in the machine shop. (See Fig. 19.)

These jigs, although involving some trouble to make, very quickly pay for themselves, as the drilling is accurate, and thus no wiring plates will be scrapped, which is the principal point in our days, when time and material are scarce and rapid production is essential.



DRILLING JIG

FIG. 19.

FUSELAGE STRUT SOCKETS.

Having completed the drilling of the wiring plates and bent the lugs, the next thing to make is the small square steel shoe which has to be attached to the wiring plate by either brazing or welding. This shoe is necessary as a stay or bed for the strut end.

The way this may be made is to take a

strip of steel equal in length to the total of the four sides plus an eighth for bends, and bend it round a steel mandril of the correct size, and weld the joint together. After this, the ends may be trued up until the shoe is $\frac{1}{2}$ in. deep. It can then be clamped onto the wiring plate in its correct position, and welded in the welding shop by the oxy-acetylene welding process. It should be noted by all that the welding must be neat and thorough, as no filing of welded work is permissible under any circumstances; and considerable care must be taken by the operator not to overheat or burn the fitting.

ANNEALING.

The batch of fittings having been completed, the next thing to do is to anneal them in a gas-fired furnace, so that they may be of the correct hardness or softness. Many excellent types of these furnaces are made by some of the best firms making gas fittings and apparatus.

The annealing furnace must, of course, be fitted with a pyrometer of an approved design, and, although expensive, these instruments pay for themselves, because they prevent fittings from being unnecessarily over-heated, and prevent gas from being wasted. They also let one know that the correct temperature has been reached, and they therefore prevent fittings which are

imperfectly annealed from being used, which, of course, is a safeguard to the firm's reputation. They are, of course, required by the A.I.D.

Gas furnaces require handling in an economical manner, or considerable waste of gas is possible, and they soon become an expensive item in the firm's charges. It would hardly be advisable to light up the furnace for a couple of small fittings, so one should wait, if possible, for a fair batch of them. It is not advisable either to purchase too large a furnace at first.

FURTHER THOUGHT.

Having outlined a generally accepted method of producing wiring plates of one kind, it is superfluous, almost, to add that this method may be adopted with certainty of quick production, to most other kinds. Of course, there are sheet metal fittings which really require the skill and thought of an expert sheet metal worker, and in many cases it is frequently necessary to experiment as to the best methods to be adopted. Two or three attempts may have to be made before a fitting is produced successfully, and in such a manner as permits of repetition work.

There are many methods of making things, but in our days, unless they are capable of being used on a commercial basis, they are useless, and further experimenting and thought are necessary.

CHAPTER IX

BOLT MAKING.

Assuming that the wiring plates used in the construction of the fuselage have been made, and bent, and passed into the finished part stores, the next question to be considered is, are the bolts in stock? If they are, so much the better, but it is quite probable that about a couple of days before they are wanted somebody may have discovered that only half the quantity have been delivered, and that it is uncertain where the next lot will come from. We will therefore assume that the hexagon steel bar required for making these bolts is in stock or can be obtained quickly.

Under these circumstances, it is decided to make an immediate start on production. The capstan lathe selected for the purpose will be a $\frac{3}{4}$-in. capstan, fitted with wire feed, and with suitable colletts, which is the technical term for the jaws in the chuck which grip the bar which is to be turned down into bolts.

The bar steel being available, a length of 6 to 7 ft. will be fed through the support attached to the lathe head on the left-hand side of the lathe and right through the lathe head until it comes through the col-

letts to where it comes in contact with a stop in the capstan head.

The next thing to do is to prepare the cutting tool, for cutting down the bar to the required size of the bolt.

The capstan lathe not being provided with tools, it will be necessary to obtain what is called a box tool holder, which has a shank turned down to fit into the capstan head, and into the box tool holder is fitted the cutting tool and the Vee guide or support for the turned bar as it passes the cutting tool. (Fig. 20.)

CAPSTAN SETTING.

The cutting tool is put into the box tool holder and held in position by means of a set-screw screwed down onto the top of the small piece of high speed steel forming the tool. This tool is formed in various ways, according to the ideas and experience of the capstan setter-up. Some prefer to fix the tool up to cut level with the axis of the steel bar, and others prefer to have the tool inclined upwards at an angle. This detail, however, will be settled by the foreman of the machine shop.

The next tool to be fitted into the capstan head tool holder will be the circular button die and holder, with special disengaging head, so that the operation of screwing can be stopped practically instantaneously at the end of the desired

length of screwed thread. The reversing of the capstan for unscrewing the die can be done by hand or with a slow reverse belt drive, whichever is more convenient.

The next tool to be fitted will be the cutting-off tool, or parting tool, in the cross slide, for the purpose of parting off the newly turned bolt from the bar.

All the stops for the semi-automatic working of the capstan having been adjusted and locked with the lock-nuts, the next thing to do will be to attempt to make the first bolt. Of course, the first few may be expected to be failures, as various adjustments will have to be made until the correct diameter of the turning is arrived at, and also till the screwing, parting off, etc., have been tested.

CAPSTAN TURNING.

It will possibly be as well to detail the operations, which can be carried out far more quickly than it takes to write it.

The first thing to do will be to start the lathe, turn on the "cutting compound" so that it thoroughly lubricates the front turning tool, catch hold of the long lever which operates the slide carrying the capstan head tool holder, and press the turning tool up against the hexagon bar steel, thus reducing it to the required size and length, which are determined by the stop.

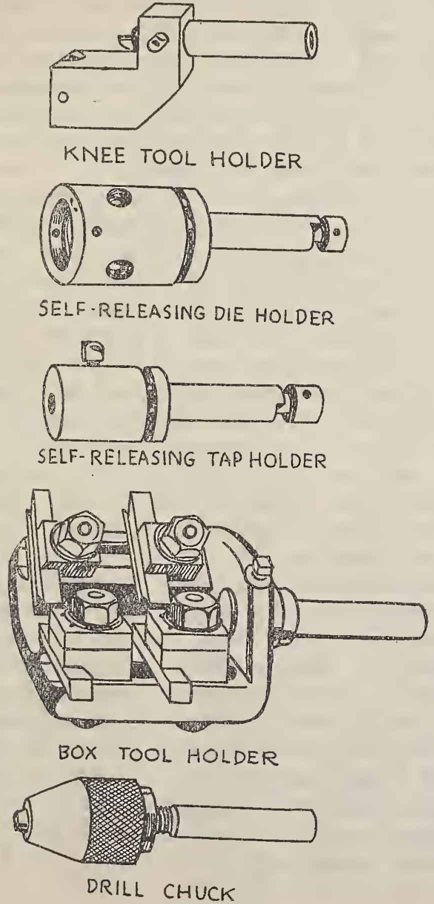

KNEE TOOL HOLDER
SELF-RELEASING DIE HOLDER
SELF-RELEASING TAP HOLDER
BOX TOOL HOLDER
DRILL CHUCK

FIG. 20.

Having completed the turning down of the hexagon steel bar to the required diameter and length, which, by the way, is all done in one cut, comprising the roughing and the finishing cut, the next operation is to reverse the movement of the lever, and move the capstan head back.

This movement brings into position the button die, or what is frequently used, when obtainable, a geometric die head, containing the dies. Pull the lever forward, and gently but quite firmly press the die up against the end of the bolt. The die will then commence to cut the thread. Continue pressing until the lever will travel no further. The die will continue to cut probably a couple more threads, and then the die head will automatically become disengaged from the hollow die head holder, and will continue to travel round with the bolt.

Reverse the belt drive, if fitted, as it should be, and the die will work itself off the bolt.

Having completed the cutting of the thread on the bolt, it now remains to part off the bolt from the bar. For this purpose we now turn to the cross slide and take hold of the feed handle and bring the tool up against the hexagon bar, which promptly cuts off the bolt, which falls into the tray underneath.

CHAMFERING.

Assuming that a number of these bolts have been made, they will have to be taken to another capstan lathe, if available, and there have the heads faced off and chamfered. This is done in one operation by the tool fitted into the cross slide tool holder. The operation consists of picking up the bolt and slipping it, thread first, into the jaws of a collett and then pressing the tool in the cross slide across the face of the hexagon head of the bolt, and cleaning off the head and chamfering. This operation having been completed, the bolt is taken out, and the operation of bolt making is finished.

NUT MAKING.

The bolt will now require a nut, and the same sized hexagon bar will, of course, be suitable for making the nuts. The setting up of the capstan for nut making consists of fitting a stop for adjusting the feed of the bar, thus allowing only the correct length of bar to be fed through. Having done this, a tool for facing and chamfering the nut should be fitted into the tool holder of the cross slide on one side, and a parting-off tool in the tool holder on the opposite side.

Also a centre bit can be fixed in the capstan head tool holder, for giving the

twist drill, which is also in the capstan head, a true start. This twist drill is, of course, a tapping size.

The procedure of work consists first of facing and chamfering the head of the nut. This being done, centre the nut with the centre bit ready for drilling. Then reverse the lever and bring the twist drill into operation and drill the hole through nut. When this is done, part off the nut, which can be tapped in a small jig in a tapping machine, which is quicker than tapping in the capstan lathe.

The time taken to produce, say, $\frac{1}{4}$ in. bolt and nut, about $2\frac{1}{2}$ in. to 3 in. long, may roughly be assumed to be about four minutes. From this it will hardly be necessary to point out how very valuable a few capstan lathes, or even one only, can be in a workshop, in case of delay in delivery of bolts from the recognised manufacturers.

MAKING EYEBOLTS.

Eyebolts are made in precisely the same way, only that round steel bar is used instead of hexagon, and the parting-off tool is shaped so as to produce a semicircular elongated end. The bolt is then put into a milling jig or clamp and the head milled between two milling-cutters. This can be done with batches of, say, about eight at a time, after which each batch is put into a drilling jig and drilled.

Should the eyebolt require to have the eye at a certain angle, then of course the jig which holds the eyebolt during the milling process is made to hold the bolt at the required angle, and thus accuracy is obtained. The accuracy of this angle is most essential, otherwise a fair pull is not obtained by any tie rod or streamline wire which may be attached to it, and inaccuracy may start a dangerous fracture.

To the inexperienced erector this item may not appear to be of much importance, but it happens to be one of those matters which strictly demand the attention of all erectors. It applies to wiring plates as well, which must be bent to suit the angle precisely, between the two points of attachment of any tie rod or streamline wire.

SNUGS.

Reverting again to eyebolts, many of these are made with a "snug" under the head. This, to those who are not familiar with this term, consists of a projection to prevent the bolt from turning round when in its correct position. This operation in the manufacture of eyebolts is usually done by using a dividing head attached to a milling machine table. This holds the bolt in position whilst the milling cutter produces the required shape, which in many cases may be described as a semi-elliptical projection, about $\frac{3}{16}$-in. deep.

CHAPTER X

LIFT PLATES.

Lift plates, i.e., those which take the main load or flying wires of the machine, frequently consist of laminated plates soldered together. These have to be made with considerable care, as much experience is necessary in knowing the additional amount of length required to allow for bending, so as to enable the various holes to be drilled accurately in position.

To enable this to be done, it is necessary to pin the laminations together and put the fitting in a jig to be drilled, after which it is best to use a cast iron or mild steel block, designed to be used as a bending jig. It will be almost impossible to describe these, as of course they are very numerous owing to the number and various types of fittings to be bent. Accordingly it is best to get the tool-maker to design one specially to suit the particular fittings required to be bent.

The value of a small fly press is considerable for many small parts, and, with simply designed jigs, an intelligent youth can produce a considerable number per day of small washers, etc.

CHASSIS STRUT FITTING.

The chassis strut fittings will now be required, and these will require careful thought, as they are made to grip the lower front spar, and at the same time pass round the compression strut. The first thing to do in making fittings of this description is carefully to set out the whole fitting on some light gauge, black-iron or steel, and bend up the fitting and tack it in shape by welding it together.

After this the portion for holding the chassis struts can be set out on the flat plate and bent up to the required streamline shape. Then the angle required by the strut can be checked.

This having been done, the fitting and manufacture of this part must be commenced. For this purpose, and to assist the sheet-metal worker or fitter employed, it would be as well to have a dummy portion of the front spar fitted onto a dummy compression spar, so as to enable the metal-worker to grasp what to do.

Also a couple of rejected struts (which, of course, should not exist) may be cut to dead size in the wood-finishing department, and handed over to the metal department, so that they can be actually placed into the position and fittings made for them, and thus it will enable the worker accurately to discover the dimensions to

which he has to work. It will also ensure the streamline portion of the fitting which holds the strut being accurately fitted to the portion clipping the front spar and the compression strut.

ACCURATE FITTING.

This accurate fitting is most necessary, otherwise the joint between the two fittings will be a very bad one, and this might lead to disaster at any moment if the machine landed on rough ground. This might occur for any of the following reasons : either the acetylene-welded joint between the two component parts forming the fitting might be weak, and badly fitted to enable the right-angle of splay to be obtained, in which case there would be gaps to be filled up with the welding ; or else the strut may never have been normally and naturally at the right angle, and may have been strained or forced into it. This procedure would either badly strain the fitting or the strut, and possibly both, and the ultimate result would be a bad failure, possibly at some critical moment.

Therefore it can easily be seen that the fitting and making of such fittings as I have briefly described requires patience and care, and the first one or two will in all probability take double the time to make that the last ones take. But that cannot

be helped; accuracy and perfect workmanship must be had.

The above remarks equally apply to the fitting to be made for attaching and holding together the two struts in the Vee shape in accordance with the design, and also for holding the steel tube forming the axle and the shock-absorber fittings.

The steel tube which forms the axle is usually of air-hardened steel, and the drilling of the holes in it, for attaching the "rubbing plates," or distance washers, against which the chassis wheels rub, and by which they are kept in position, entails considerable trouble owing to the hardness of the steel. I have found by experience that frequently a shop-made flat diamond-pointed drill is superior to any twist drill for drilling the holes for the taper pin. Turpentine forms the best cutting compound or lubricant.

The wheel is kept on the axle by means of a large washer, about $\frac{3}{16}$ in. thick by about $1\frac{1}{4}$ in. long, which is an easy push-fit over the axle, secured into its place by another taper pin.

These washers are, of course, turned out of solid bar on turret lathes, and are of the usual class of bar work for which turret lathes and capstan lathes are made. The washers are usually made by girls doing repetition work in the machine-shop.

STRUT SOCKETS.

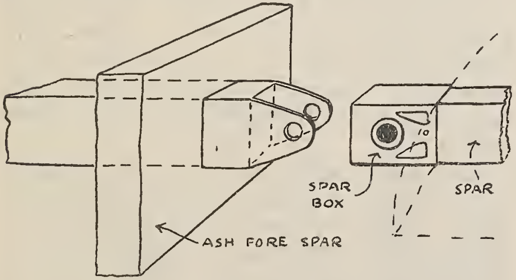
The strut sockets for the centre plane will be the next fittings to consider. These will take the form of sheet steel streamlined sockets on wiring plates, attached to the top longerons into which the struts will be bedded. The bracing wires will be attached to the lugs for bracing the centre plane.

These sockets will probably be made of 18 gauge sheet steel, welded to the wiring plate, which will be made of about 12 gauge steel. As these fittings occupy a position of considerable importance, like other parts they must be made accurately to the dimensions given. Care must be taken that the process of welding in no way impairs the strength of the fitting.

Considerable care must be taken to see that the wiring lugs are fully up to size, and also that all radii on the wiring lugs are fully up to dimensions. It is important also that the pin-hole in the lugs is correctly in position and that the hole after drilling is accurately finished to dead size with a reamer. These points must be carefully looked to, or you may be sure that they will be detected by the A.I.D. inspector.

The result will be that he will lose his confidence in you, and he will consequently be liable to treat every fitting put

up to him for his inspection with considerable suspicion. This is the most undesirable thing that could possibly happen. If possible, try and convince the A.I.D. by actual practice that he cannot teach you anything, but don't imagine it; that is fatal; see to it yourself, and don't pass the job on for somebody else to do. He may think that if you are too tired to do it, it is of not much importance, and then the trouble commences.



SPAR ATTACHMENT
FIG. 21.

If everybody did their job, I think that most firms would find that there would be considerably less work for everybody to do. Shorter hours would be possible, and greater output would follow.

MACHINING SPAR BRACKETS.

The spar brackets for attaching the lower wings to the fuselage consist, for our pur-

pose, of mild steel stampings. These, of course, must be machined all over, and the lugs, where the hinge pins pass through, carefully machined to a specified angle with the rest of the bracket so as to give the wings the required angle of incidence.

The best way to machine these is to clamp them to a machining jig on the bed of the table of a milling machine, about four at a time, and pass a couple of side and face milling cutters past the jaws of the stamping, and then mill out the centre portion with a single cutter. When this work is complete, they can be transferred to another jig and milling machine and have the outside surfaces of the jaws milled.

This being done, the next thing to do is to mill the lug to the required angle, between milling cutters, and then fix the bracket for drilling the hinge pin-hole; the lightenings can then be drilled out and finished with a round file. The only remaining work to be done is the drilling.

TYPES OF METAL FITTINGS FOR AEROPLANES II

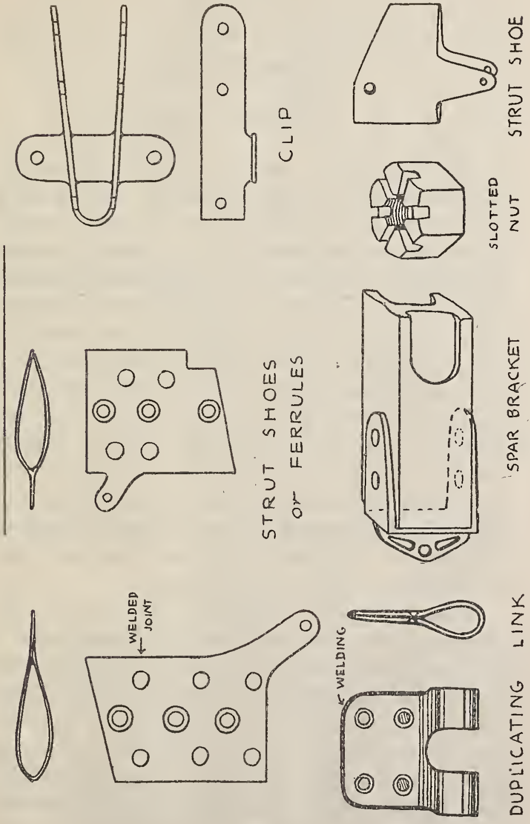


FIG. 22.

CHAPTER XI

THE TAIL PLANE.

The tail plane will now have to be considered. For the purpose of this article one may assume that the tail plane is almost semi-circular in shape and that the framework is formed of light steel tubing. This will be in four lengths; the first piece being straight, and forming the base or trailing edge of the plane, two pieces of tube forming quarters of a circle on each side, and one piece forming the centre portion of the leading edge, nearly straight.

It may be assumed that the diameter of the tube is about $\frac{5}{8}$ in., and that it is about 20 gauge. All joints have an internal liner pinned in position and brazed.

This, of course, must be well done, and although the oxy-acetylene blowpipe is a delightful instrument to do brazing with, it may be just as well to point out to all concerned that its use for brazing is not allowed by the A.I.D. Of course, there may be exceptions to the rule, but these exceptions apply to special circumstances, which I do not propose to deal with here.

GAS BRAZING.

Therefore, one has to resort to the gas blowpipe, of which there are many makes. Those made by the well-known Warrington firm of Fletcher Russell and Co. may be relied upon to do good work, and for this light work an $\frac{1}{2}$-in. gas blowpipe is ample if a good supply of air and gas is obtainable. Some soft brass wire, or brazing strip, should be obtained, and although borax forms a very good flux, some of the brazing compounds now on the market are preferable, and in my opinion better results are obtainable.

Having prepared the semi-circular portions of the tail plane and tested the radii in a jig, these may be taken to the brazing hearth and the joints brazed and cleaned off. After the brazing is complete do not do as I once saw done, cool off with water. It is decidedly bad practice. Let the job cool itself.

JUNCTION PIECES.

The next parts to put onto the semicircular portion of the tube will be the right-angled junction pieces, which are specially-made steel tube fittings, for forming the connection with the straight tube composing the trailing edge of the tail plane. These will be pinned and brazed, or, as an alternative, sweated on with tin-

man's solder, after the semi-circular tube ends have been accurately cut to length.

Before this is done, however, slide on, into their respective positions, the hinge fittings for the elevator flaps, which have been milled and bored out of solid bar steel. The position of these hinge fittings involves working to the very finest limits of dimensions, and the greatest possible care must be taken to check their position before finally drilling, pinning, riveting and sweating them into position.

It is certainly most essential that a steel jig be first made and accurately checked and passed by the A.I.D., and used afterwards to locate the fittings accurately whilst being fixed.

Unless these precautions are taken, the tail plane will probably not fit standardised elevators, which may be made by another contractor, and will involve endless trouble to all.

Before fixing the straight tube into the right-angled junction pieces it may be as well to try the ribs of the tail plane in their respective positions, in case any special adjustment of lengths is necessary. This having been done, the straight tube may be finally fixed and the ribs, which are of box-section sheet steel, afterwards fixed and riveted into position, when the wooden stringer, which lies parallel with the trailing edge, has been passed through them.

This work being done, the tail plane is complete except, of course, for the covering with fabric and doping.

PRESSING TAIL RIBS.

Having got so far it may be as well to give some idea of the construction of the ribs and of the method and design for a steel jig for making them.

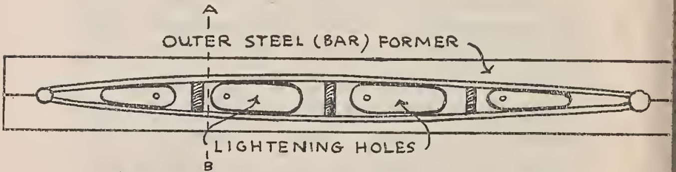
The ribs, one can assume, are made of box-section sheet steel with suitable lightening holes, the steel being 24 gauge.

The first thing to do will be to make a steel former of bar steel about $\frac{3}{8}$-in thick, less twice the gauge of the steel in thickness, and precisely the same length. The next thing to do is to cut out one of the steel blanks, out of which the ribs will be made, adding to the width the turn up all round to form the flange, plus the turn in, which will be about $\frac{3}{8}$-in. wide.

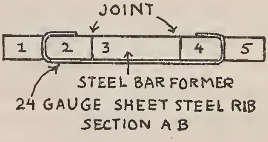
Having done this, lay the steel former on the blank of steel sheet and carefully locate it all ways in the centre. Then mark off the bolt holes previously drilled in the former, where the lightening holes come in the rib, and drill these holes in the steel blank. (See Fig. 23.) These two holes, in the former and the sheet steel blank, are for the purpose of temporarily fixing bolts to pass through and to hold the steel blank rigidly in position whilst being flanged on the former.

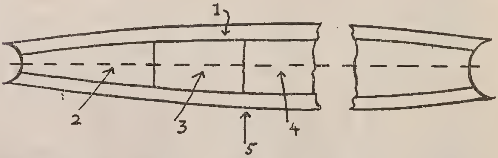
Before proceeding further, it will be necessary to make a female former in halves out of steel bar to fit on the partially-formed rib when the first portion of the

FIG. 23.



PLAN SHOWING RIB IN STEEL FORMER





PLAN OF INNER STEEL FORMER

FIG. 24.

flange all round has been turned up. This female former is for the purpose of preventing the steel rib from buckling when the last operation of flanging is being carried out.

A COMPOSITE FORMER.

As the first steel former could not be removed from the rib when all the flanging is completed, it must now be removed and replaced with a similar former made in five pieces (see Fig. 24). This being made in five pieces with the three centre pieces, Nos. 2, 3, and 4 removable, it is easy to see that when the double flanging is complete the work may be removed from the bench vice and the centre pieces removed. Then the two long outer strips, 1 and 5, can easily be removed from the rib.

What remains then to be done is to mark off and cut out the lightening holes and finish up with a smooth file. Examine the finished ribs and make good any buckle, or defects, that may be observed.

ASSEMBLING.

After this the vertical sheet-steel web-stiffeners may be riveted in position to prevent the web from buckling under load. This having been done, the rib may be examined, and, if passed, sent to the A.I.D. After which it may, with the others, which are of varying lengths, be assembled in the framework of the steel tube, thus forming the entire frame of the tail plane when riveted and sweated into position.

The method of rib making, above described, has given most satisfactory results in actual practice, and may be relied on generally. The trouble of making the steel formers is very quickly paid for owing to the speed and accuracy of production, as they permit of moderately-skilled workers being employed.

ELEVATORS.

The elevators which are attached to the tail plane should now be put in hand. As they are of similar construction, the only difference being the shape and size, it will be unnecessary to describe their construction in detail. This also applies to the rudder and fin.

CHAPTER XII

CONTROL LEVERS.

The levers on the elevators and rudder we will assume, firstly, are made of mild steel stampings. That being the case, they must be sent into the metal machine shop to be bored out to fit onto the steel tubing. This can be done by either "chucking" them in a chuck in a lathe, or fixing in a drilling jig and drilling $\frac{1}{16}$-in. below size and finishing with the correct sized reamer.

These levers, however, may be made of hollow sheet steel, in which case they will be edge-welded, with stiffening pieces at the ends for attaching the "D" shackles attached to the control cables. And a steel boss will be riveted to the centre for attaching them to the steel tube, to be drilled and pinned thereon.

In this case a considerable amount of work is in hand, and a certain amount of experimental work is necessary. The drawings should be carefully studied. Assuming these levers to be of streamlike section, the first thing to do will be to get the pattern-maker to make a wooden pattern for the former, on which will be bent and formed one-half of the lever, which we can assume to be made out of 20-gauge sheet steel. The former should be made,

both male and female, so that the sheet steel can be paned out and afterwards finished to shape by pressing, or squeezing, against the cast-iron former.

After the sheets have been made correctly to shape, they can then have the hollow bosses attached to them by means of rivets and brazing, the whole being assembled for this purpose on a mandril.

The hollow bosses are of about 14-gauge sheet steel, and are generally "spinnings." These being an extremely difficult thing to make, it is best to obtain them from certain firms who make a speciality of this class of work, as they would be too costly to make, not to say unsatisfactory, except in the hands of skilled metal spinners equipped with the necessary tools.

FIXING THE LEVERS.

The levers which have just been described are required for the rudder and the elevators. They are attached to the steel tube framing of the rudder and elevators by means of taper pins, which are carefully put through the bosses of the levers and the steel tube and riveted over. After this, the whole is carefully sweated together with solder. This solder must be the best tinman's solder, for it forms the strongest joint, and flows more evenly and neatly than plumber's solder into the small crevices and openings. Any superfluous solder should be cleaned off with a rag or small scraper or fine file while still hot.

CHAPTER XIII

TAIL-SKID FITTINGS.

The various component parts of the rear skid will next have to be considered, and we can here deal with the most important of them.

The skid-fork will probably be a mild steel stamping. This requires to be machined up with considerable accuracy and precision to fine limits. To proceed with the work, it will be best to have the socket-end turned down in a centre lathe, as it will serve as a gripping piece for the jig, which will have to be made to hold the skid-fork whilst it is going through the operation of being milled.

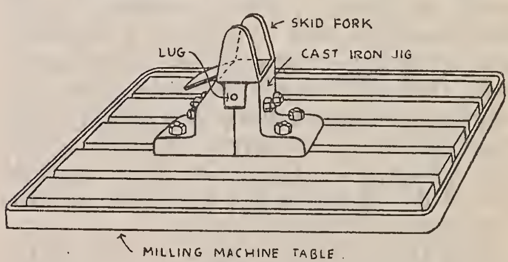
For this purpose it must be sent to the marker-off and be centred. It can then be sent to the metal machine shop, where it will be placed between the centres of a small lathe, say a 6 in. centre engine lathe. Here the outside will be turned down to the dimensions shown on the drawing.

MILLING OPERATIONS.

After this, the stamping will be sent to the milling machine to have the fork-ends milled. For the purpose of holding the stamping, a heavy cast-iron jig had better be made, or a mild steel clamping jig (see

Fig. 25), which holds the socket-end firmly, whilst the fork-ends project upwards. Possibly it may be advantageous to mill about three fork-ends at once, and the jig can be made accordingly if desired.

The next thing to do is to set up the milling cutters on the spindle of the milling machine. These will be "side and face" cutters, which means that they are capable of cutting on the flat face at the side as well as on the circumference.



SKID FORK IN JIG.

FIG. 25.

They can be set up so that they mill the outside faces of the fork, and so there will, of course, be a fixed overall dimension. The distance apart of the cutters must be maintained by collars placed between the cutters on the spindle, and well tightened up to prevent the cutters from slipping when the machine commences to cut, keys and keyways may be used.

These two cutters will clean up the faces

of the forks, after which the cutters can be replaced with another couple of cutters to finish the inside of the fork. Or, if the stock of milling cutters happens to be extensive, possibly one of the right width can be found which will guarantee the accuracy of the width of the cut.

EDGE FINISHING.

The next thing will be to finish the edges of the fork. These can be done in the vice, with a file, by the fitters, but, of course, the whole of the work can be done on the milling machine, if the stock of milling cutters is sufficiently extensive. In this case another jig must be available for supporting and gripping the fork-ends whilst the edges are being milled and the top of the forks rounded to the true curvature. Naturally, this method is preferable, as accuracy is guaranteed, but this could only be done in a shop with a fair-sized machine-tool plant, unless time was no object.

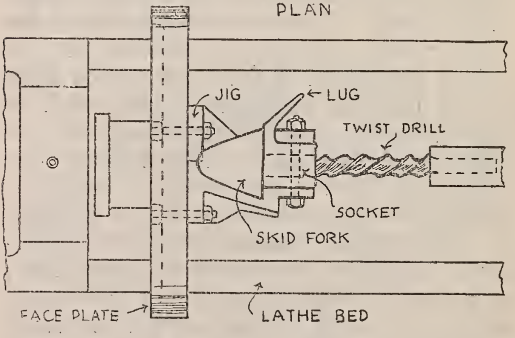
DRILLING THE FORK-ENDS.

The operation of milling having been completed, a drilling jig must be made for drilling the holes in the fork-ends for the skid-bolt to pass through.

BORING THE SOCKET.

Having completed these operations, the next thing to do will be to prepare a cast-

iron boring jig which will grip the socket end of the fork whilst it is being bored out. This jig can be made either to bolt onto the face-plate of the lathe or to be stood on the table of a large drilling machine, whichever is available for this work, so that in the case of a small machine shop, no undue inconvenience may be caused (see Fig. 26).



JIG FOR BORING SKID FORK SOCKET.

FIG. 26.

The boring-out having been completed, the skid-fork may now be considered ready to be sent to the inspection department. They should easily pass through here, as most of the operations are machine work, and, with the male and female gauges to check dimensions, accuracy should be assured.

SKID-STAY FORKS.

The next items are the forks for skid-stay, or stay-tube sockets, as some people call them. These articles, though simple to look at, are not exactly easy to make, and may cause a considerable amount of trouble and scrap if not manufactured in the right way.

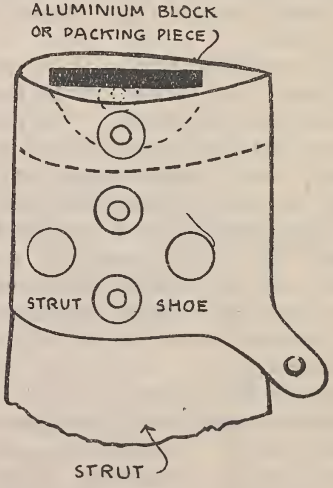
For this purpose they will be made out of solid steel bar, turned out to profile on a capstan or turret lathe. This operation consists of turning down the socket-end to the taper shown on the design, and boring the fork-end to the profile, the socket leaving the lathe with the fork-end solid. This will have to be cut out on a milling machine, and here the trouble commences unless a good jig is made which will hold the socket-end firmly whilst the fork is being milled out.

The jig for this purpose should consist of a mechanism which will grip the taper of the socket firmly. For this purpose make a strong grip-jig, something on the lines of a machine vice, or similar to Fig. 25, only with special jaws. This will enable about three or four sockets to be done at once, all being placed in the jig in a line. In this way fairly quick production becomes possible immediately. The drilling of the A.G.S. pin-hole in the fork-end will necessitate a drilling jig, which can be built

up of mild steel, or cast-iron, whichever is most readily obtained.

THE SKID FITTING.

The steel-clip fitting for attaching the stay tube to the fuselage is made of two pieces of 16-gauge sheet steel, each bent



SKETCH SHOWING
STRUT SHOE IN PLACE
FIG. 27.

to fit the longeron and also to form the lug to which is attached the stay tube. The edges of the two pieces forming the lug

are brazed together, with the addition of a small washer on either side, the hole afterwards being reamered out. The object of the washers is to increase the bearing area for the attachment bolt which passes through. On the inside face of the fitting is a steel socket, into which the cross tube is fitted. This socket is welded on, and into this is fitted the cross tube which forms the support for the bearing for the skid post.

CHAPTER XIV

STRUT-END FITTINGS.

It will be noticed that at the end of interplane struts, which in many types of machines are made of spruce, a steel fitting in the form of a streamlike band or ferrule passes round the strut end. Into this is fitted an aluminium packing piece, which fits onto and forms the connection between the eyebolts, which pass through each spar, front and rear. This packing piece, with the band, keeps the struts into position and takes the thrust.

This streamline band is formed of about 20-gauge sheet steel in one piece, the two edges at the rear or thin end of the streamline being butted together and welded. This welding must be well done and neat, as no filing nor cleaning up of welded joints is permissible. Afterwards it must be well annealed.

MAKING STRUT SOCKETS.

The best way of making these strut sockets is to have a cast-iron former cast, the pattern being equal in length to about 9 inches of the spruce strut at each end. This being cast, it must be carefully cleaned up, and then it is ready for the

sheet steel blank, which is to form the strut socket, to be bent onto it and round it.

Before cutting up sheet steel, it is as well to get a piece of zinc, or thin common black iron, or tin, and bend it round and cut it until the required shape and pattern is obtained, after which it can be flattened out and used as a template for marking off

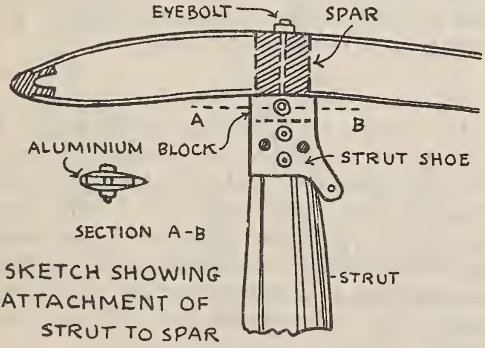


Fig. 28.

the actual blanks. It may be as well to point out, however, that the outer extremities of the socket should be left quite full, and more or less shapeless, as in actual practice it is found to be safer to finish off the final shaping after the welding is complete, in case of any twist or deformation having occurred during welding, as is not infrequent. Also, the ends require to be

trimmed with a file to suit the aluminium packing pieces. Where large quantities are required, these are, of course, pressed out.

This being done, the bolt and pin-holes will be carefully set out and marked off ready for drilling, and drilled. After which the fittings can be considered finished and can be sent to the inspection department. When finished with here, it will be sent to the wood-components department to be fitted to the struts.

PACKING PIECES.

The aluminium packing pieces which fit into the strut sockets are generally made off metal patterns, and the castings usually obtained are nearly perfect. Thus they require very little cleaning up. The only machining to be done consists in drilling the bolt-hole and milling out the radius slot where the eye-bolt fits into the packing piece.

This work is usually done in a small milling machine with a milling cutter of the required diameter.

In assembling the strut ferrules and packing pieces onto the strut ends, care must be taken to see, and make sure, that the aluminium packing piece beds onto the spruce strut. Unless it does so, it is possible that the strut may not do its work, and might be the cause of a failure of the whole machine.

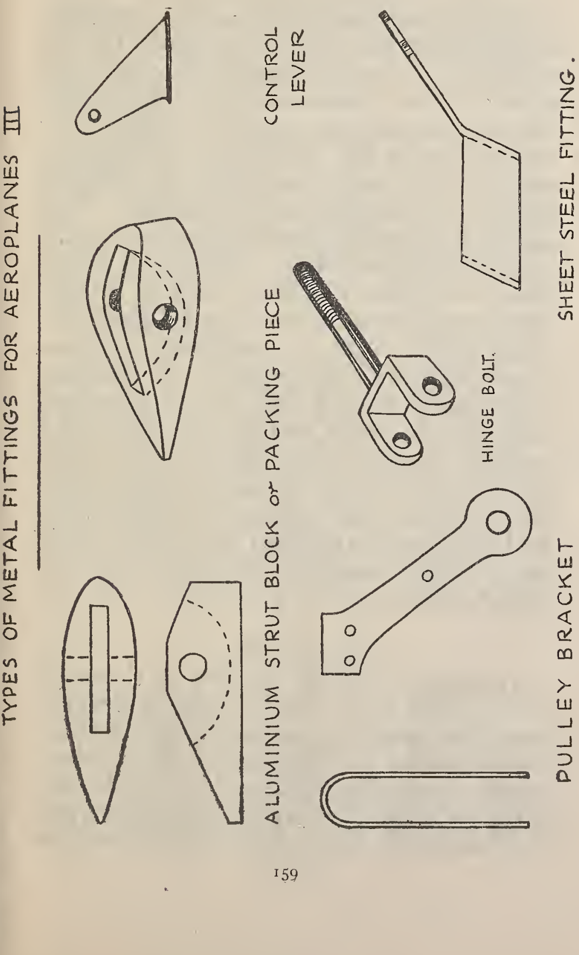

TYPES OF METAL FITTINGS FOR AEROPLANES III
CONTROL LEVER
ALUMINIUM STRUT BLOCK or PACKING PIECE
HINGE BOLT.
PULLEY BRACKET
SHEET STEEL FITTING.

Fig. 29.

SMALL CLIPS.

It frequently happens in a large contract that amongst the many items called for are small clips. These clips may be pipe clips or wire clips. Sometimes the clip is semicircular, sometimes square, in fact, they are all shapes and sizes, but each clip of any certain type or size must naturally be strictly to dimensions and limits. The gauge of the metal used in their manufacture is often very thin. When this is the case it frequently happens that it is possible for this work to be done by girls.

To enable girls to manufacture these clips, and save the expense of making costly press tools which take a considerable time to make and also to save using presses on work they need not be employed on, it is best to make a few simple jigs which can be used in the bench vice, and the power obtained from the use of an ordinary hammer, or the squeezing action of the vice.

CLIP JIGS.

Assuming that we require a thousand clips to clip $\frac{3}{8}$-in. copper petrol pipes, the best thing to do is to get two pieces of steel, exactly equal in thickness to the required width of the clips, each we can say for our purpose about 3 in. long by an inch wide. File them flat and square all ways, then on

one mark out your clip, and file this up to form a female gauge of the pipe clip, only leaving it the same thickness as the required width of the clip. After this file up the other piece to form a male gauge corresponding to the other piece forming the female gauge.

When these are complete, put them both together and mark off half the thickness of the gauge of metal on each one, file this off, and you have a male and female gauge to suit each side of the desired clips. These then form the die and the punch for making the clips.

The next thing to be done will be to fit a couple of pins into the ends of each end of the male portion, and then drill holes in a corresponding position in the female portion for them to slip into. This being complete, all that remains to be done is to cut off strips of the metal to be used, a shade wider than required, and cut off into suitable lengths, equal to the total length of the clip when flattened, plus a small amount, which must be the same in every case.

CLIP PRODUCTION.

Having got so far, it may be possible to start production.

The first thing to do will be firmly to grip the female portion of the jig in the vice, with the clip side uppermost, then drop the other half of the jig onto it, lift

slightly, and slide a piece of metal between the two and accurately locate it in the middle, a few taps of the hammer and the clip will be found to be practically shaped up. The next thing to be done is to drill the holes in the clip for the attachment screws.

The same jig can be made to act as a drilling jig. For this purpose drill the two holes through the jig in the required position. These holes will, of course, pass through the first clip, and all others can be drilled the same way, after which the surplus metal may be filed off and the clip will be complete.

This method is a simple but effective way of producing small clips quickly and accurately, and can, of course, be elaborated if desired. Also the jigs being simple of construction, two or three can be made quickly, or any jig worn out can be replaced. Also it enables girl labour to be utilised, providing the gauge of the metal used is not thicker than 18 gauge.

CHAPTER XV

ENGINE PLATES.

The production of the front and back engine plates by hand is a job that should only be put into the hands of an experienced sheet-metal worker, as the thickness of these being about 10-gauge which equals 0.128 of an inch makes it a fairly tough job. However, it can be done, and is done, but it is not like shelling peas.

The back engine plate, we will assume, is of rectangular shape, the edges and lightening holes all being flanged at right angles to stiffen the plate. Therefore, in marking off the plate on the sheet, all necessary allowances must be made for the flange and bends. This can be easily done first before actually cutting out the engine plate, in the following manner.

We can assume that the edge of the plate, which forms the top and bottom flange, when in position, is about $\frac{1}{2}$-in. wide, with $\frac{3}{16}$-in. radius. Therefore, take a piece of steel plate, 10-gauge in thickness, say 5 in. long by 3 in. wide, and mark off a $\frac{1}{2}$-in. flange either end, and then put it in the vice with a piece of bar steel having a $\frac{3}{16}$-in. radius, and hammer

the steel plate with a mallet over this flanging jig.

When this has been done at both ends and a $\frac{1}{2}$-in. flange accurately formed, having a $\frac{3}{16}$-in. radius, take the piece of steel out of the vice and measure it over all, and find out if it measures 4 in. across the two flanges, or if it is more or less, and accordingly make your necessary calculations and allowances. Doing this will enable you to cut out the plate to the dimensions required to give you enough material to work with, and to enable you to produce the engine plate to the precise required dimensions.

In cutting out and flanging the lightening holes had better be started and finished first, as any buckle or distortion can be eliminated in the plate before the important hole for the engine attachment is cut out.

Before commencing to work on the plate it is as well to anneal it thoroughly, according to the instructions laid down for annealing steel plates, after which the lightening holes should be carefully set out. Take care to leave enough metal for flanging, plus a margin for cleaning up, after flanging.

All flanging should as far as possible be done with hard wood mallets, to prevent the metal from being thinned down and the surface damaged.

Having completed the flanging of the lightening holes the flanging of the edge of the plate may next be taken in hand.

A WARNING.

Before proceeding further, I think it may be advisable to mention to readers of these articles that, in marking off steel plates, there is a certain danger in using a sharp-pointed steel scriber, as I have known steel plates which, when marked off thus, have, on being bent or flanged, developed a distinct fracture along the scriber line, and fittings have had to be scrapped from this cause.

To prevent this arising I suggest that a hard brass scriber be used as much as possible, in place of a steel scriber. Centre-pop marks also frequently cause a tear in metal.

FLANGING OUT.

The marking off of the flange being completed, the flanging may be commenced. If a wooden mallet be used, then a cast-iron or mild steel block can be used as an anvil. If a steel hammer be used, then a hard wood block must be used. Few people seem to realise this.

Also, it is well to note that the quickest way to take twists, kinks, and dents out of sheet metal is to hammer it with a steel hammer on an end grain piece of wood. For some reason best known to themselves

some people prefer to hammer a piece of metal furiously on an anvil, which generally ends in the metal being either reduced in gauge, or dented all over with hammer marks. Of course, these look nice, if done in an artistic pattern, but, fortunately, we have not yet arrived at that stage in the manufacture and decoration of aeroplanes. We may come to it after the war.

THE ENGINE HOLE.

After the flanges are completed and the corners welded and the whole plate has been tested for squareness and flatness and for its general truth, the centre hole for attaching the engine may be marked off and carefully cut out, and the attachment bolt hole carefully and accurately drilled. No "allowances" can be permitted at all, and dimensions must be worked to very minutely.

In fact, it may be deemed advisable to chuck the engine-plate in a lathe and bore out the hole finally to ensure its being accurate. In removing the greater portion of the centre of the hole it is advisable to drill a considerable number of holes, and cut out the centre by chiselling through the centre of these holes, if not bored out in the lathe.

The front engine-plate may be dealt with in the manner previously described, after which each one should be carefully annealed.

ATTACHING ENGINE-PLATES TO FUSELAGE.

Before drilling the bolt holes in the fuselage for attaching the engine-plates, it is best to clamp the plates in position and test their accuracy, and satisfy oneself that the plates are dead in the centre all ways. If this is not very carefully done, general trouble may be expected, especially in trueing up the machine ready for flying, as it will be impossible to line the engine up true with the fuselage.

CHAPTER XVI

PETROL TANKS.

The manufacture of the petrol tank might now be considered, and, as this has to fit in between the longerons, it is necessary to work strictly to dimensions, or it may not fit the position.

The workmanship must be extra good, as it has to stand internal air pressure, and all joints, riveting and sweating with solder must be perfect, otherwise serious leaks may develop and cause fire to break out in the air with fatal results.

The material frequently used is tinned-steel sheets of best quality, about 22 to 24 gauge, riveted up with $\frac{1}{8}$-in. snap-headed copper rivets, and best tinman's solder.

The pitch of the rivets is about 1 in. apart. They must be in a dead straight line along the joints, and all rivets must be very carefully snapped, and all riveting must be concentric with the centre-line of the rivets, otherwise they are liable to rejection.

As it is generally a difficult matter to replace rivets, any divergence may mean a tank being scrapped, which is an expensive item to the contractor.

TANK SHELLS.

The first thing that can be started is the shell. This will be made of two sheets or one sheet, according to the size of the tank and sheets. The theoretical girth of the tank should be most carefully ascertained from the drawings and set out on the sheets together with sufficient margin for flanging and forming the joint at the bottom of the tank where the joint is usually placed.

There are various kinds of joints. The simplest, of course, being the lap joint, riveted, and sweated after riveting. The usual joint is a double-flanged joint, the flanges tightly locking each other, and sweated with solder each side of plate.

SIDE PANELS.

The joint for the side panels is generally made in the following manner:—The side panels having been carefully cut out to the required dimensions, the edges are flanged with a $\frac{1}{2}$-in. flange. The side panel can then be placed inside the shell plates, the edge of the flange of the side panel, which will be outwards, being adjusted all round inside the shell so that the edge of its flange is about $\frac{1}{2}$-in. from the edge of the shell plate.

The side panels are soldered in position, and the flange of the outer shell flanged back over it. After this, the spacing and

marking out of the rivet holes can be proceeded with. But before fixing in the side panels, or ends, there is a stiffening diaphragm to be put into the tank shell.

RIVETING ENDS.

Having marked out the rivet holes for the panels, the quickest way to drill these will be with a small electric portable drill, such as are made by the General Electric Company, this work being done on the tinsmith's bench. As soon as the drilling is complete, the rivets can be put in and carefully riveted over with a small ball-paned hammer, and finished up with a small semicircular snap.

The riveting being complete, the next thing to do is to spread a neat film of solder over the rivets and into the joint. It must be clearly understood that a thin neat film of solder only is required, and not a thick mass of uneven lumps.

THE STIFFENING DIAPHRAGM AND FITTINGS.

The next thing to do is to fix the diaphragm plate to stiffen the shell.

Before proceeding, it may be as well to set out the position of any fittings or connections, which have to be attached to the tank by means of rivets, or other ways of attachment, as it will not be possible to do so when both the side panels are in position.

Having attached all fittings, the remaining side panel can be put in, riveted up, and soldered, and all rivet-heads lightly and neatly floated over with solder.

REMARKS ON SOLDERING.

With regard to soldering, what is actually required is to consider the soldering-iron a paint brush, and with it cause the solder to flow evenly and cleanly where required. I have met some people who imagine that the process of soldering consists of attaching as many isolated lumps to the work as possible.

If any remark is made about possible leaks owing to untidy rough soldering, they proudly tell you there is plenty of solder, which is just what is not wanted. Half the quantity evenly spread on clean metal with a well-heated iron, thoroughly cleaned, and with plenty of flux, does the job a heap better.

TESTING TANKS.

Assuming that the tank is finished, it must now be tested for leaks. One of the recognised ways is to neatly fill it with paraffin, attach a pressure-gauge to it on one of the fittings or outlets, and then with a motor foot-pump, or large bicycle pump, fill the tank with 10 lbs. per square inch air-pressure. Close up all known outlets and leave the tank for 24 hours, then note

the pressure in the tank, and look for leaks and make good.

JOINING PIPES.

With regard to preparing copper pipes, etc., it occasionally happens that pipes have to be joined. Assuming that we have a $\frac{3}{8}$-in. by 20-gauge copper pipe to join we can do this various ways, but no way must be adopted that reduces the bore at this particular point. Therefore, to overcome this difficulty, expand each end of the pipes to be joined for a length of $\frac{3}{4}$ in., then obtain a piece of the $\frac{3}{8}$-in. by 20-gauge copper pipe, carefully cut off $1\frac{1}{2}$ in., square the ends, and slightly taper them off, slide this piece into one of the expanded ends of copper pipe to be joined. This must be a slightly loose dropping fit. Then braze this liner in.

Having done this, clean off all superfluous spelter and insert this short length of pipe into the other expanded end of copper pipe, press tightly together, and clamp up. Then braze in a similar manner and clean off.

Another way of joining tubes is to expand one end only and insert the end of the other piece of tube into it and then braze. This makes a simple neat joint, but some people may not consider it quite so strong.

STRETCHING AND TESTING—JOINING AND SPLICING CABLE.

The splicing of steel wire cables for controls is work that can only be done by experienced men. It is simply absolute waste to experiment and to attempt to do this work if you are not trained to it. But other methods of attaching cables to shackles and eyelet bolts are frequently adopted for 5, 10, 15 and 20 cwt. cables in aeroplane and seaplane work.

Before cutting a wire cable, place the cable at the point to be cut into the flame of a blow-lamp, then bind with thin iron wire with two separate bindings, leaving a space between each binding of about $\frac{1}{8}$ in., and cut with a sharp steel chisel.

A SIMPLE JOINT.

To make the cable fast to an eyebolt or shackle, place the cable through the shackle, ring, or eyebolt. Bring about 6 in. through. Then bind this 6 in. to the side of the cable with 20-gauge copper wire for a length determined by the size of the cable, the bindings being about $\frac{1}{16}$ in. apart. Then sweat with solder, and then cut off the ends not required. This method is frequently used, and is, if anything, slightly stronger than an ordinary spliced joint. This is not a surmise, but an actual practical fact, which has been proved.

STRETCHING CABLE.

Before any cable is cut to the dead length required, it should be stretched up to its full load. This acts as a test of the strength of the cable, and prevents it from becoming slack after being placed in position in the aeroplane. Also, the stretching probably prevents one having to scrap the cable owing to its developing excessive length after being in use for a time.

TESTING AND STRETCHING CABLES.

The necessary material for the cable testing and stretching apparatus consists of two sound pieces of deal or pitch-pine, 16 ft. long, 9 in. by 2 in. These will have to be planed all over, after which two pieces of 9 in. by 9 in. by 3 in. will be sandwiched between the two ends of these long pieces of timber so as to keep them 3 in. apart, on edge. When fastened to the legs they will stand on, they should be about 3 ft. 6 in. above floor level.

These 9 in. by 9 in. by 3 in. packing or distance pieces will be securely glued and bolted in their permanent position. After this, $\frac{3}{4}$-in. holes must be drilled through the centre of each piece of timber on each side-face, exactly opposite each other, about 9-in. centres, to allow of the tension-head of the apparatus being moved, and the length of the apparatus being adjusted to suit different lengths of cable.

THE TENSION-HEAD.

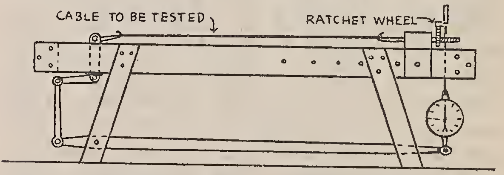
Having completed the apparatus so far, the next thing to do will be to construct the tension-head. This can consist of a piece of sound, well-seasoned ash, about 1 ft. 6 in. long, by 9 in. by 3 in. This will have a $\frac{3}{4}$-in. hole drilled through the 3 in. thickness of the piece, in the centre, and $4\frac{1}{2}$ in. from one end, so that the $\frac{3}{4}$-in. bolt, which passes through the side of the 16-ft. timbers, can pass through this piece also and hold it in position. On the sides of this short piece of ash two chocks, each 9 in. long by $3\frac{1}{2}$ in. by 2 in., will be glued and bolted. And further, through the edge of this piece of ash, which is 3 in. thick, will be drilled a $\frac{3}{4}$-in. hole. This is for the $\frac{3}{4}$-in. tension-bolt to pass through, to which the cable which has to be stretched is attached.

At the other end of the 16-ft. timbers will be fixed a 10 to 1 bell crank-lever, or combination of levers. The short end will project upwards between the two 9 in. by 2 in. timbers, and to this will be fixed a suitable swivel link to which to attach the cables.

At the long end of the lever arrangements and fittings will be made for attaching a spring balance, capable of reading up to a load of at least 300 lbs. This will be used for the purpose of indicating the

amount of strain to which the cable is being strained. (See Fig. 30.)

The many uses for testing purposes to which this machine can be put, and the valuable data obtained thereby, quickly



CABLE TESTING OR STRETCHING MACHINE

FIG. 30.

repay its cost. The use of one of these machines is badly needed in most works using cables and ropes. It is easily made, and cannot get out of order. Also, accurate readings can be obtained by any intelligent person.

CHAPTER XVII

CASTLE NUTS AND THEIR MANUFACTURE.

Regarding the use of nuts, it frequently happens that "castellated" nuts have to be used, and, assuming that supplies have run out, which occasionally happens, it may cause considerable delay in waiting for further supplies from the actual manufacturers. Therefore, having described in the Tenth Instalment of this article the method generally adopted for making small bolts, it may be as well to add in this Instalment a method frequently adopted for cutting the slots of castellated nuts.

A small or large plain milling machine will be utilised for this purpose.

To the table of the machine attach a machine-vice, and in between the jaws lay a rectangular bar of mild steel which has been "shaped" all over. The length of the bar being not less than the length of the jaws, the size of this bar will depend on the size of the nuts to be castellated.

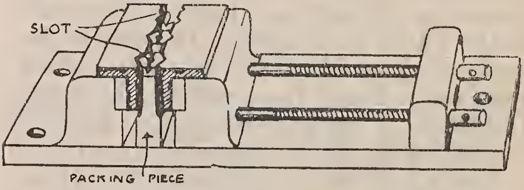
This bar of steel may be a few hundredths of an inch less in width than the width across the corners of the nuts (see Fig. 31). This is for the nuts to rest on, to keep them up to the slitting-saw.

For the purpose of holding, say, half a

M

dozen nuts in between the machine-vice jaws, in their correct position for slotting, we must prepare two pieces of angle steel with vertical Vee slots cut in each of them. These Vee slots are for the purpose of gripping the corners of the nuts firmly, whilst they are being castellated.

Owing to these Vee slots being required in the angle steel pieces, it will necessitate them being made out of the solid bar, the angle for laying on the machine-vice jaws



JIG FOR HOLDING NUTS TO BE SLOTTED

FIG. 31.

being either milled, planed, or shaped out. As these two pieces of angle steel will be subject to considerable work, it will be as well to make them at least ½ in. thick all over, and case-harden them.

THE USE OF THE JIG.

Having made the above jig for castellating the nuts, all that has to be done is to fill up the new angle jaws with as many

nuts as they have Vee slots in them and carefully see that each nut beds down equally on the packing-up strips under them. Tighten up the jaws firmly, fix the slitting-saw in the mandril, and adjust the height of the milling machine table, and thereby regulate the depth of the slitting-saw cut in the nuts. Start the machine and the cross-feed and lubricate the saw with the cutting compound.

By this means half a dozen nuts can be quickly slotted across two flats of each of them. As soon as this operation and cut is finished, stop the milling machine, unscrew the machine-vice slightly, turn each nut round, and slot twice more, and the six nuts are done. By this means nuts are slotted or castelled quickly, cheaply, and accurately.

HINGE BOLTS.

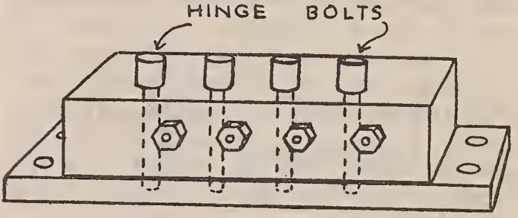
The milling of small hinge bolts is a subject which may be useful to consider, also the drilling of the pin-hole.

The small hinge bolts having been turned out from the capstan lathes, and being made out of round bar, will at this stage of manufacture only have cylindrical heads, therefore it is necessary to prepare a jig to hold them in whilst the heads are squared on the sides and the tops formed to a radius (see Fig. 32).

MAKING A BOLT JIG.

The jig may be formed in the following manner:—

The pattern-maker will be instructed to make a plain, rectangular pattern with the ends flanged for bolting down onto the table of the milling machine. The length will be about 10 in., the width 4 in., and the thickness about $3\frac{1}{2}$ in. (see Fig. 32).



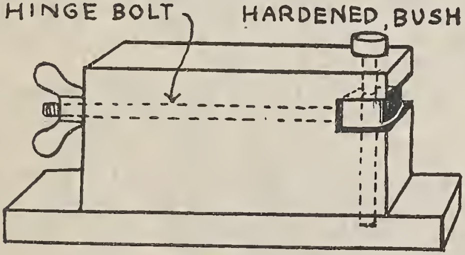
MILLING JIG

FIG. 32.

Plane up the top and bottom surface of the castings, which will be cast-iron. Then mark out the longitudinal centre line of the casting on the top side. On this line space out, at about 1-in. centres, the holes into which will be placed the hinge bolts to be milled. Drill these holes right through the casting to the bottom.

The next thing to do is to provide some means of fixing the bolts to be milled,

therefore a hole must be drilled through the centre of the side of the casting, at right-angles to the existing holes, at each one, in such a position that the circle of the fresh hole cuts the existing hole by about one-third of its diameter. Into these holes will be fitted plain bolts, with nearly one-third of their side filed off, so as to form a taper wedge against the bolt which is in the vertical hole to be milled. To



DRILLING JIG
FIG. 33.

prevent the wedge bolt from turning round and causing trouble when other bolts are required to be inserted for milling, a feather is fitted to the wedge bolt and a slot is filed in this bolt hole to take it.

METHOD OF USE.

Having completed this jig, the method of working it will be to take, say, six bolts

and drop them in the vertical holes, making sure that they are right home. Then firmly tighten up the nut at the end of each wedge bolt, thus locking all the bolts to be milled in position. Fix the jig on the table of the milling machine with bolts, and then fix the milling cutters. Adjust the height of the table and proceed with the work.

Having completed the milling of the heads of the hinge bolts, the next thing is the drilling of the pin-hole in them, and for this purpose a small drilling jig can easily be made (see Fig. 33).

Having dealt with the construction of many metal parts necessary for the construction of aircraft, and possibly sufficiently to enable those new to the Industry to gain some insight, one may as well next deal with the finishing up of the various parts of the machine.

These important component parts may be dealt with in the following order, namely, the centre-section plane, the top and bottom main planes and ailerons, the tail plane and elevators, the fin, and the rudder and fuselage.

CHAPTER XVIII.

COMPLETING THE CENTRE SECTION.

The centre plane being of wood, it will be sent to the paint and varnishing department, where it will receive (subject to this system being adopted by the management) two coats of spirit-varnish all over, then the small riblets and rib-noses will be covered top and bottom sides by a strip of half-inch India tape, glued on, the total length of which will be about 2 ft. 3 in. for each length of tape.

As soon as the glue is dry and set, the top and bottom edges of all parts forming the centre plane will receive one good coat of white dope-resisting paint, as will all fittings, tie rods, wiring plates, bolts and nuts. The centre plane will then be ready for inspection by the A.I.D.

The same process applies to the main planes, tail planes, elevators, fins and rudders, with regard to the white dope-resisting coat of paint. Of course, spirit-varnish is not put on steel-tube constructions, which are only painted with the dope-resisting paint.

COVERING.

This work of painting having been carefully completed, these parts will be sent to the covering shop.

The centre plane is the first member to be covered. During the time the covering department has been waiting for these various components to come along it has been busy cutting out and machining up the covers, and putting the small eyelets for laces into the covers of the fuselage and many other small jobs.

A WORD OF WARNING.

Here I pause to point out a word of warning. Before attempting to fit on the covers on the planes and stretch the covers taut and sew up, take care to see that the linen fabric is absolutely dry and well-aired. Unless you can be fully satisfied regarding this point, stop covering until you have taken the necessary steps to dry and air the fabric.

The reason for this is that however little percentage of dampness or moisture the fabric may contain it will be contracted in area, and however tight it may be stretched and sewn on, it will relax and become quite slack on coming in contact with the warm, dry air of the dope room. It is fairly safe to say that no amount of doping will succeed in bringing up the tautness of the fabric as it is required for first-class wings, and the finished article will be a disappointment.

PUTTING ON THE FABRIC.

In covering the wings it is usual to put on the covers over the leading edge.

Stretch the cover over the top and bottom of the ribs, then stretch the fabric to the trailing edge and tack down with a few fine gimp pins. Sometimes this is done with pins. The fabric should then be stretched lengthways and all seams straightened from the front to the back.

After which the two surplus ends of the fabric should be cut off, leaving only about half an inch of each end to turn in and make a seam. The sewing up of the seam may then be commenced.

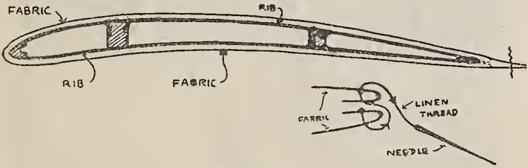


FIG. 34.

The first stitch should be made by passing the needle through the fabric from the inside, pulling it through and passing over the edge, then across the gap to the fabric on the top of the wing. Here the needle is again passed from the inside of the fabric to the outside, and the stitches both drawn together (see Fig. 34). This has the effect of neatly and tightly drawing together the ends of the fabric.

STRINGING.

The wing will now have to go through the process of "stringing." This consists

of putting a loop of string over the fabric and round each rib, and knotting and carrying the end of the string about four inches farther on and repeating the same operation. This is done to each rib, on which there will be about eight or nine loops.

This is for the purpose of attaching the fabric to the ribs, preventing the fabric ripping, and generally helping to distribute the load. The lines of string are afterwards covered with strips of fabric, with frayed edges, to give a neat, smooth and strong surface.

CHAPTER XIX.

DOPING, VARNISHING AND PIGMENTING

The wing will now be ready for doping, and will be taken to the dope room. Before commencing doping the temperature of the room must be at least about 70 deg. Fahrenheit. This temperature is demanded, not for the purpose of causing the contractor trouble and annoyance and the expense of putting in and maintaining a heating apparatus, but for the purpose of obtaining satisfactory results with the dope employed, namely, good adhesion, a smooth surface, and what may possibly appeal to the contractor, rapid production.

This remark specially applies to the coat of aeroplane varnish which is applied to the underside of the wings, as some makes of varnish will take seven to eight hours to dry and sometimes longer, and with a good temperature it is easy to save half an hour, which means a lot to the contractor whose space is limited, and thereby output is increased.

DOPING WINGS.

The wing which has to be doped can be laid on some trestles made a convenient

height, say about 2 ft. 9 in. On these will be laid or fixed pieces of wood about the same length as the spars, and the wing-spars will rest on these and nowhere else. Taking the weight, these will prevent the fabric from being strained, and possibly punctured.

The dope will now be put into a can capable of holding, say, about a quart, and with a narrow slot in the top like a letter-box slit, through which to put the brush. A brush about 4 in. wide should be used to spread the dope.

In putting on the dope it is necessary to put it on, and especially to spread it, quickly and evenly. Take plenty on the brush and work it evenly into the fabric backwards and forwards, and then finish by working it at right-angles to your last way of spreading. Then leave it to dry thoroughly before attempting the next operation.

In doping it may be as well to go to the trouble of instructing the dope hands that to dope a wing properly they should not attempt to start on about half-a-dozen spots at once, they must start at one end and work first of all on a small patch of, say, 2 ft. by 1 ft. 6 in., and finish this before starting elsewhere. By this means it may be possible to get an equal quantity of dope all over the wing, and not patches of dope, as is frequently the case with

inexperienced hands, who do not know any better, and occasionally who don't think. Some are honest enough to tell you so, as I have frequently heard them say, "I don't think." I do appreciate their honesty, although it is a trifle annoying to those holding responsible positions.

FRAYED FABRIC.

Having completed the first coat of dope, the next thing to do is to obtain the frayed or "spaced" fabric from the stores. This is ordinary fabric of ordinary width, in which the threads called the "weft," namely those which run longitudinally in the fabric, are left out about every two inches for a width of about half an inch. This is cut into strips and laid on over the rib-stringing and well doped down, also strips are laid along the edges for the purpose of strengthening the fabric and preventing it from tearing.

The method of attaching this frayed fabric is to dope the surface well and take a length with both hands. Lay it against the doped surface, or on it, and then rub it well down, either with the fingers or a piece of fabric. Then well dope over it with a brush.

When this has well set, the final coats of dope may be applied.

IDENTIFICATION MARKS.

The next thing to do is to set out the identification mark according to the instructions and official measurements given. This is painted on by a painter with some experience in sign-writing or fine work.

When this is dry the "khaki" pigment is put on the top of the wing. Generally two coats are necessary. This being dry, the wing is turned over and given the final coats of varnish and left to dry.

When dry the wings, with the ailerons and the tail plane, the elevators, fin and rudder, which have been doped, will be taken to the finishing shop to have the external fittings attached.

CHAPTER XX.

THE FINISHED PARTS, STORES, AND THE ASSEMBLING SHOP.

The wings, ailerons, tail plane, elevators, etc., having been received from the dope shop into the finished-part stores, they can here be examined and passed by the inspector. If suitable accommodation and room is available, the wings can be conveniently stored in racks in a horizontal position, the racks being double-sided, preferably fixed with a walking space all round.

In this way the top right and left-hand planes can be stored on one rack, and the bottom right and left-hand planes can be stored in another rack. Thus quite a large number of wings, elevators, or tail planes can be stored in a small space until required in the erecting shop or for despatch.

Similar racks are useful in the dope room to store planes when a large number are being pigmented or varnished, whilst they are drying. It is far preferable to keep the planes in racks instead of leaning them in piles against walls or partitions, where they are liable to be damaged by people's feet walking by, besides scratching the edges and distorting the wing, owing to it being improperly supported.

A PARTS ASSEMBLY SHOP.

In all works an Assembling Shop situated conveniently near to the Erecting Shop should be provided. This shop we can assume for our purpose to be about 30 ft. square, with two narrow benches along the walls opposite to each other. About five pairs of trestles, with 3-in. by 2-in. rounded bearers, sufficiently long to support the whole length of the wing, should also be provided.

In this shop, on the walls, a few small bins for holding the external fittings in can be fixed up, and if possible a small electric portable drill for drilling pin-holes. Into this shop all wings, elevators, ailerons, etc., can be brought to have their external fittings put onto them. To many managers this may seem a unnecessary sub-division of the erecting shop duties, but it will be found to save time, decrease wasted room in the erecting shop, specialise labour in their work, facilitate cost-keeping, expedite the erection of complete machines, lessen the labour and supervision of the erecting-shop foreman, centralise responsibility for perfect work, and generally speed up output. So it seems worth while.

THE COMFORT OF WORKERS.

Further, the bulk of the work can be done by one man, assisted by about six

intelligent girls, who, if they are at all suitable for the work, easily pick it up in about a fortnight, especially if conditions for work are comfortable. There should be plenty of air, light, and reasonable warmth, which is as necessary for the planes, etc., as the workers.

There are some people who say, "work, and keep yourself warm." This is possible if you are shifting and erecting heavy steelwork, digging a hole with a pick and shovel, or, better still in cold weather, firing a marine boiler; but aeroplane work does not happen to be similar to any of these blood-circulating occupations. In many cases it requires a certain amount of delicacy of touch and care and patience, none of which qualities contribute to warmth.

Therefore, it is as well to give attention to the subjects of air, light, and warmth, as it is quite possible for a large shop full of workers, say a hundred, to spend twenty-five per cent. of their time in thinking how cold it is. To estimate the cost of this occupation, ask them to book a quarter of an hour every hour to this on their time sheets, and then ask the Cost Office for the account at the end of the week.

The wings, ailerons, tail planes, fins, rudders, etc., can be brought into this assembly shop to have their external fittings attached. The wings, for instance, require

their lift plates and eyebolts put on and split-pinned, and the spar brackets or other hinges attached. In fact, an immense amount of incidental yet important work can be done here, thus saving a large amount of room required for complete machines.

CHAPTER XXI.

ERECTING THE MACHINES.

The complete erection of the aeroplane has now to be considered briefly.

We can assume that the fuselage skeleton is complete ; this will be put on two trestles in the erecting shop, and the trestles should have some simple form of adjustable head, so that the height of the work on them can be varied. This is essential, especially in this instance, as the under-carriage has to be fitted onto the fuselage, and it is handy to be able to raise or lower the fuselage without having to look for a few pieces of loose wood. These do not invariably form a solid packing for the fuselage such as is required to enable the fuselage to be held in a horizontal position.

ACCESSORIES IN THE ERECTING SHOP.

The under-carriage having been attached to the fuselage and all the bolts put in and split-pinned up, the axle can be put into its position. The shock-absorbers can be then wound on and the aluminium streamline fairing attached. It will not be advisable to put on the wheels until the machine is practically finished, as the tyres deteriorate, the covers get dirty and

frequently torn, and everybody makes footsteps of them. Therefore, a pair of small wooden Vee trestles should be made, into which the bearing-ends of the axle can rest.

The axle, however, should be lashed firmly to the chassis-struts so as to prevent the load from coming on the shock-absorbers, as these being made of rubber will deteriorate and become stretched if the machine is left standing for a considerable time, as sometimes occurs before final delivery.

As a considerable amount of work will have to be done which involves the workers being about eighteen inches above the floor level, it would save a considerable amount of waste of time and litter of old boxes kicking about the shop if a few 6 to 8ft. forms are made on which the workers can stand.

PRELIMINARY FITTINGS.

The next thing to do will be to fix the tank bearers and prepare for the reception of the tanks for the petrol and oil supply. As soon as these are fitted, it will be as well to put in the instrument board so that instruments can be set out in their respective positions and screwed into their positions after any necessary cutting and fitting has been done.

As soon as they are in position the cop-

persmiths should be detailed off to fit in the copper pipes and bends from the instruments to the tanks, at the same time the installation of the controls can be commenced, the rudder-bar being fixed in position, and the "joy-stick," or control pillar, for working the aileron and elevator controls.

Having put these in, the streamline fairing on the fuselage can be fitted. In some machines this is an independent unit in one piece, in others it is built up on the fuselage in skeleton form and covered with fabric, which is afterwards doped and varnished. Also, the fuselage will be covered round with fabric, which is stretched on and tacked to the longerons, and the tacks finished off or covered over with a small half-round beading.

FIXING THE TAIL.

The tail plane can next be attached to the fuselage, but before being finally fixed in position it must be tested to see that it is fairly and squarely at right-angles to the longitudinal centre-line of the machine. This can be done with long trammel points or a steel tape, and measuring from the left and right-hand tips of the tail plane to a fixed point on the centre-line of the fuselage; this must be dead right and an equal measurement on either side. Differences, however small, cannot be per-

mitted, and all necessary alterations must be made until the dimensions are accurate.

ENGINE FITTING.

For the moment, as most work is being done at the tail-end of the machine, it may be considered a suitable time to lift the engine into position, but before lifting it in it is necessary to secure the tail of the machine in some way to the floor, either with ropes fastened to temporary cleats screwed to the floor, or some heavy weight. Unless this is done the machine will tilt up when the engine is installed, as the weight of the engine is considerable.

It is not advisable to expect the engine erectors, either with or without help, to lift the engine into position. The lifting should be done with a half-ton worm-geared chain tackle, and some good, reliable $1\frac{1}{2}$-in. rope, and a couple of stiff bird-mouthed bits of wood to put between the rope slings to prevent them from bending or breaking various parts of the engine or chafing or cutting themselves. Also, incidentally, it is advisable to attach the tackle to something which is capable of standing at least double the weight of the engine. Gas pipes and electric conduits, or coat-hooks, should be considered out of bounds, and may be neglected as anchorage for the lifting tackle.

Having installed the engine in position,

it is best to put an adjustable trestle underneath the nose of the fuselage in case the ropes which hold the tail end of the machine down give way. This incident has occurred before now, with disastrous results to the engine.

It will then be necessary to check the engine to see that it is in line with the line of flight, and with the fuselage we have constructed. The line of flight will probably be that of the top longerons. It is from this line we must work, as it is our only base from which to start.

The engine which is being installed in this case is of a radial type, and will, therefore, be fastened to the front and the back engine-plates, which are attached to the fuselage. Therefore, we must satisfy ourselves that the front engine-plate is truly at right-angles with the line of the top longerons. Also, the plate must be tested to make sure that it is transversely at right-angles with the centre-line of the whole fuselage. Unless this is done, the engine and propeller will always have a tendency to look either to the left or the right, according to whichever side the engine-plate inclines.

The reason for this demand for accuracy is that the aeroplane is designed to fly normally in a dead straight line, and it will not do this if the engine is not fixed squarely and truly in the fuselage.

PETROL CONNECTIONS.

The installation and the coupling up of the petrol and oil pipes must next be taken in hand. Before any pipe of any description is finally coupled up in its position, the pipe should be thoroughly tested, preferably under steam or air pressure, for strength and leaks, and also to make absolutely sure that there are no obstructions of any kind inside its whole length; this precaution is most necessary and cannot be too strongly impressed on all concerned; in fact, I consider that in view of the importance of this matter it should come under the Inspection Department (A.I.D.).

The bending and the adjusting of pipes should only be done by workers who are skilled in this class of work, as dents and kinks of any kind should not be tolerated in the smallest degree, as it causes inefficiency in the whole system of piping. Also all spelter should be carefully cleaned off all brazed joints and the pipes generally should be finished off in a high-class workmanlike manner. Any deviation from this standard is undesirable.

The revolution counter, and the shaft for driving it, will next be required to be fitted and coupled up.

During the time that the pipes were being tried and fitted into position, the cowling over the engine should have been in the

hands of the coppersmiths and panel beaters, and can now be fitted on.

FITTING THE COWL.

The engine cowl is generally made of about 22-gauge aluminium sheet, and is either pressed out, spun or beaten to shape.

In measuring up for the quantity of metal sheet required to make a cowl, it is just as well to measure round the outside circumference of the cowl on a sectional elevation. It should be borne in mind that the metal has to be pressed or hammered to this shape without distorting or thinning, although, of course, this does take place in a small degree, but it is not desired to a measurable extent.

Before proceeding with the final fixing of the cowling and aluminium fairing generally, it will be as well to fix the centre plane struts into their sockets on the top longeron of the fuselage, attach the centre plane to same, and put the bracing wires into position. This work requires the taking of careful measurements, and the accurate adjustment of the fork-ends, so that an equal tension on each strut and bracing wire will be assured. Excessive tension is not required, as this only puts additional work on to the struts and fittings, and they are only designed for a certain load, which it is not desirable to exceed. When putting in the bracing wires, the insertion of

the split-pins in bolts should be left over, in case any alteration has to be made in the tension or position of any bracing or fitting or bolt.

ASSEMBLING THE MAIN PLANES.

The assembling of the main planes can be done in two ways. Firstly, by attaching one, say, right-hand or left-hand top wing first, using a trestle to support it, and attaching the bottom wing on the same side afterwards, supporting this also on the trestle, until the interplane struts and lift wires are put in and adjusted to both wings.

The alternative method is to stand both wings on their leading edges and then put the interplane struts into their respective positions, together with the bracing wires, and tighten up the whole lot just sufficiently to hold them together. Then the wings can be carried by the erectors to the machine and attached as a whole with the aid of a couple of pairs of tall steps.

With reference to the above methods, there are advantages and disadvantages in them both, and it may be as well to give them consideration, to save waste of time and difficulty to those who have not had the experience of erecting wings on finished machines.

As regards the first method, it can be recommended for the use of erecting shops where there is a lack of skilled men used to

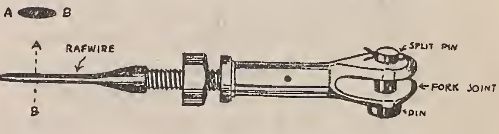
handling aeroplane wings; secondly, it enables the erectors in the case of a new machine to set the wings up truly to the correct dihedral angle and angle of incidence at the same time, and to measure up the correct lengths for the bracing wires after the struts have been tried up and fitted to their permanent positions.

WIRING LENGTHS.

With regard to the last reason, of course, the mathematician will naturally come along and say that it is possible accurately to calculate the length of any side of a triangle, and that, as he is able to do this, the practical advantage which I have set forth is of no use, and need not be taken into account. I quite agree that his statements are perfectly correct, up to a point, and the point is, that the mathematical calculations do not tell one what effect the tightening of the bracing wires will have on the structure as a whole, or how much one bay will contract at the expense of another expanding, and because the mathematician has calculated to five places of decimals that a lift wire will be, say, 7.61500 ft. long, it most probably happens, when the machine comes into the hands of the skilled erector who is responsible for tuning up the machine for her test flight, that the required length of the lift wire will be found to be, say, 7.54 ft. long, the loss of 0.075 in.

being due to the various struts bedding together under the strain and tension required in a machine tuned up for flight.

These remarks, therefore, emphasise the necessity for allowing an ample margin for adjustment in wires. Also, screw threads should not be too short, and under no circumstances should streamline wires, which are exceedingly difficult to get at the present time, be cut by irresponsible workers, without authority. (Fig. 35.)



STREAM LINE WIRE WITH FORK JOINT

FIG. 35.

The disadvantages of erecting wings separately is that it entails more trouble in having to have high pairs of steps for the men to get up to the top wing to fix up the struts and attach the bracing wires, and it is sometimes awkward to drill split-pin holes when perched upon the top of a pair of steps about 10 ft. high. Also, there is the expense of the trestles.

With regard to the second system: this method works well in the hands of experienced erectors, either in the works or out in the hangar, when erecting a machine which has just arrived from the makers at

the flying ground, as it saves time and trouble in having trestles and long pairs of steps and planks, and all split-pins can be fitted on the ground. The disadvantages are, that this method is only suitable for the erection of wings onto machines which have been previously assembled, as it does not enable accurate dimensions of bracing wires to be taken.

MAKING A SHOP PROTRACTOR.

The wings having been erected on the machine, the first thing to do will be to test the dihedral angle and the angle of incidence. For checking the dihedral angle, we shall require a protractor. However, a protractor similar to those used in the drawing office will not do, as it would not have sufficient length of base to give the correct general angle of the surface of the wings, nor is there any means of indicating what the angle is should one be used, so we must make what will be called a "shop protractor."

For this purpose we will obtain a piece of mahogany or beech, 6 ft. long by about 4 in. wide, by $\frac{1}{2}$ in. thick. We will mark off the centre of this piece of wood, and, with a square, cut or mark a fine line across it. At $2\frac{1}{2}$ in. either side of this centre line mark points, and then cut half the piece of wood away and halve another piece of wood into it, at right-angles. This piece

of wood will be 5 in. wide by about 12 in. long.

Onto this piece of wood, when it is fixed, continue the fine line already marked on the long piece right across. This line represents the zero line of the pointer, which will be hung from a centre about $\frac{1}{2}$ in. from the base

The next thing to do is to drill a $\frac{1}{8}$ in. hole through this centre, in the piece of wood. Then get two pieces of 12-gauge aluminium or brass, about 1 in. square, each with a $\frac{1}{8}$ in. hole drilled through the centre, and a hole at each corner big enough to take a $\frac{1}{4}$ in. by 2 gauge brass screw. Next obtain a $\frac{1}{8}$ in. bolt or metal thread and bolt the plates on to the piece of wood, each side. Then place the metal plates squarely in position and screw them on.

These plates will form the bearings of the small $\frac{1}{8}$ in. pin to which is attached the pointer. The pointer should be similar in design to a large watch-hand, about 10 in. long, of fairly heavy design at the sharp pointer end, so that the weight of it will always cause it to hang in a perpendicular position.

Before bolting on the pointer, take a large pair of finely-pointed dividers and scribe a segment of a circle on the side of the long piece of wood. On this line will be laid a piece of aluminium, about $1\frac{1}{2}$ in.

wide, and equal in length to about 1/6th of the circumference of a 10-in. circle, this being screwed to the piece of wood which forms the protractor.

On this will be marked, in the centre with a fine pointed scriber, the zero line of the pointer. This zero line will be obtained by placing the protractor on the surface of anything handy in the shop, which has been checked with a spirit level and is known to be truly level, on two packing blocks of equal thickness.

Then set out in $\frac{1}{2}$ degrees about 5 degrees either side of the centre line carefully, and check these lines, indicating the degrees with a level protractor.

Having constructed the protractor, it will be as well to give it two or three coats of spirit-varnish to help to prevent it from warping, and then it may be considered ready for use.

CHAPTER XXII.

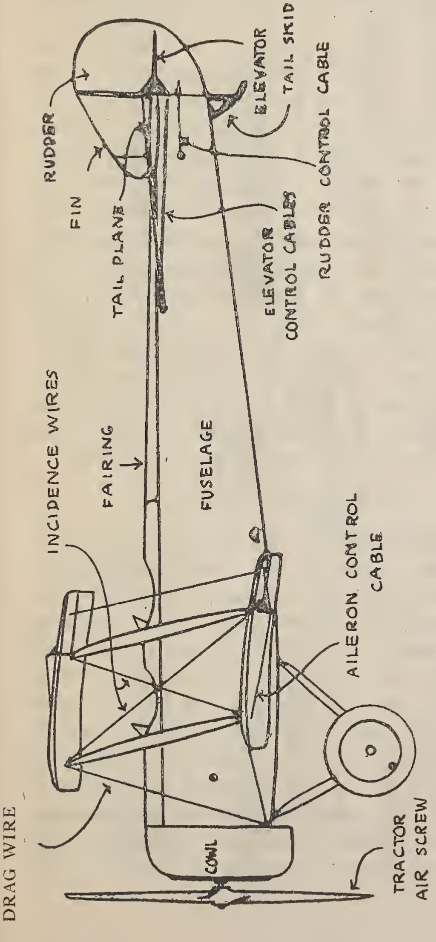
CHECKING THE ANGLES OF THE WINGS.

To check the dihedral angle of the wings of an aeroplane, the first thing to do is to consult the plans showing the general arrangement of the machine, or some other competent authority if this information is not available on the drawings.

Having obtained the drawings on which, we will assume, is the necessary information, the first thing to do is to ascertain where the line of flight traverses the body of the machine. In our case, we will assume that the top surface of the longerons of the fuselage are parallel to the line of flight.

This being the case, our work is fairly easy, because we have a ready-made base line to work from. But we must not accept this without first checking it, in case any discrepancies exist. Therefore, the longerons must be tested with straight-edges, each about 3 ft. long, placed at intervals on the top of the longerons and sighted through.

This operation will satisfy us that the fuselage is not twisted, and further, that the top surface of the longerons is straight and true.



SIDE VIEW of TYPICAL TRACTOR
-BIPLANE-

FIG. 36.

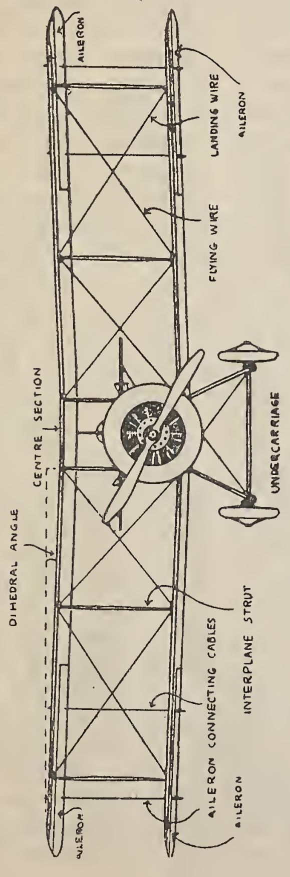
O

Having satisfied ourselves on this point, the next thing to do is to level up accurately the top surface of the longerons, both longitudinally and transversely. This may mean packing up or lowering the tail of the machine, and then securing it firmly in this position with weights or any other available or suitable means; further, the machine should be supported direct, and brought level laterally, by putting packing-pieces under the ends of the chassis struts. Don't level up by putting packing under the tyres—which ought not to be fitted until later—for a tyre may deflate after the levelling is done, and so throw all our levels out. And don't pack up the axle, because the lashing of the axle to the chassis struts may give a bit and upset our levelling.

GETTING TO WORK.

Having done this, we can commence to check the angles of the top main planes, or wings. For this purpose we shall require a pair of high steps to enable the foreman erector to place the protractor on the underside of the front part of the wing, preferably on the line of the bottom surface of the front spar; we may then expect to read any angle on the protractor between 0 deg. and 6 deg., this being the extreme dihedral angle which is likely to be wanted.

We will assume that the design of the machine calls for an angle of 3½ deg., but



FRONT VIEW of TYPICAL TRACTOR
- BIPLANE -
FIG. 37.

the angle of the wings, as erected, is only 2 deg. Adjustments must now be made.

FUNCTIONS OF BRACING WIRES.

Before being able to make these adjustments we must consider how to do so. For this reason we must study the functions of the bracing wires, namely, the lift wires, the landing wires, and the incidence wires. The lift wires start from the fuselage and take an upward and outward course, being attached to the underside of the top main plane by the lift plates. These wires may be termed the Inner Lift Wires, because they are in the inner bay, formed by the centre plane struts and the inner struts.

The Outer Bay Lift Wires are attached to the bottom of the inner bay struts, and run upward and outward, being attached to the lift plate at the junction underside of the top main plane with the outer struts.

The Outer Lift Wires are attached to the plates at the foot of the outer struts, and these also take an upward and outward course, being attached to the underside of the extension or overhang of the top main plane near the tip, though in some machines, on which the overhang of the upper plane is short, there are none of these wires, the lift being taken by the spar itself on the cantilever principle.

Owing to the direction of attachment of these wires, it can easily be seen that when

the machine commences to fly, and the top main planes commence to lift, that the effort will be transmitted through these wires unless they fail, or the bottom wing collapses.

These Lift Wires are sometimes called Flying Wires and sometimes Load Wires.

LANDING WIRES.

The Landing Wires must next be considered. These wires run in exactly the opposite direction, as they start from the wiring plates on the underside of the centre main plane, on the top of the centre plane struts, and take a downward course, being attached to the lift plates at the bottom of the inner bay struts. The Outer Bay Landing Wires start from the wiring plates at the top of the inner bay strut and are attached to wiring plate at the bottom of the outer struts on the top of the lower wing. These wires take the strain and load of the wings when landing, or the whole load of the machine when upside down, and by their direction transmit the whole load to the centre plane struts.

These Landing Wires are sometimes called Anti-Load, or Anti-Lift, or Anti-Flying Wires, but Landing Wire is the most convenient and generally used term.

INCIDENCE WIRES.

The Incidence Wires as used, form a diagonal bracing fore and aft, between

the interplane struts, and according to the amount of tension and the length of each wire, control the angle of incidence, or angle of attack, of the wings.

TRUEING UP.

Having briefly described the principal wires which go to form the bracing of a machine, we can now revert to the subject of trueing up the machine and checking the dihedral angle and bracing up the wings to the desired angle.

Having erected the wings on the machine complete, and tested the angle with the protractor, we find this is only 2 deg. instead of 3½ deg. This shows that the wings require lifting at the tips, so we must proceed to lift them with the wires, which are all more or less slack, not having been tightened up, as required finally for flight.

The first thing to do will be to slack off the Lift Wires a trifle, and then increase the tension of the landing wires to bring the wings upwards, starting with the inner bay landing wires attached to the tops of the centre plane struts and finishing up with the outer landing wires. Only a slight alteration in the tension may be necessary, this being obtained with a few turns of the barrel of the strainer, or "turnbuckle," as it is called officially, or with a few turns of the barrel of the streamline wires, whichever are used.

The lift wires may then again require attention, for tightening up the landing wires may possibly have tightened them up too much, owing to the consequent slight deformation of the parallelogram which is formed by the vertical struts on each side and the top and bottom spars above and below. The lift wires will be slacked off to the required tension by adjusting the turnbuckles to suit.

Having done this to both the back and front spar, it will be as well to try the planes again with the shop protractor, and it is possible that with luck the right dihedral angle may have been obtained. If not, it is necessary to keep on doing it till the angle is correct.

THE ANGLE OF INCIDENCE AND THE CHECKING OF IT.

We must now turn our attention to the angle of incidence, this being checked by placing the straight edge or base of the protractor on the under side of the wing, one end of the protractor being on the trailing edge and the other on the leading edge, and observing the angle indicated. If the angle is too flat, then the leading edge wants raising.

This is done by tightening the incidence wires which are attached to the top of the rear struts and run to the bottom of the front interplane struts; having previously

slackened the incidence wires from the bottom of the rear struts to the top of the front struts. This has the effect of lifting the leading edge of the wing. The opposite incidence wires from the top of the front struts to the bottom of the rear struts must be slacked off to match.

This being done, the angle of incidence should be again tried with the protractor as close as possible under the centres of the struts, and midway in between as well. If the angle of incidence is now found to be correct, then the erection of the wings may be considered complete, with the exception of the controls.

The ailerons must now be assembled in their places on the planes if this has not been already done when assembling the wings, as it should have been. And the aileron control wires should be fitted.

CHAPTER XXIII.

ATTACHING AUXILIARY SURFACES. MOUNTING THE TAIL UNIT.

The tail plane can now be fastened onto the end of the fuselage. As this is of a fixed position design, it simply means that the attachment bolts have to be put in and the nuts screwed up and split-pinned, the whole being attached to the metal attachment plates provided for it.

The small bracing wires from the tail plane spars to the fuselage must also be attached. These, of course, are for the purpose of staying and bracing the tail plane and preventing it from twisting in the air when flying.

THE FIN.

The fin will have to be placed in its position on the top of the tail plane and bolted on, and the stay wire attached. The fin being made of steel tubing, as previously described, it may hardly be necessary to mention that the rear end of the fin is formed with a stout steel tube, onto which are attached the hinge fittings for the rudder.

In some machines, however, the rudder-post is a separate steel tubular post, fixed

to the stern-post of the fuselage, and the rear edge of the fin is attached to the front side of it, while the rudder is hinged to the rear of it.

THE RUDDER AND ELEVATOR.

The rudder will now be the next thing to attach, and it is at this stage, and in other similar stages, that accuracy of work and the necessity for care in assembling hinge fittings will come forward. Owing to the fine limits of deviation allowed from the fixed measurements of hinges, any slight error will lead to scrapping the whole job, with consequent waste of time and labour and material.

The rudder is attached to the steel tube by means of the small hinge fittings, which in this case are of the usual male and female design, with a small pin passing through both portions to keep them together. The pins are kept in their places in the hinge fittings by means of a washer and small split-pin.

The elevator-flaps will be similarly attached to the rear edge of the fixed tail plane.

WHAT HAS BEEN DONE.

We have now erected all the principal parts of the machine. To the front of the Fuselage are attached the Upper and Lower Main Planes, with their Ailerons,

and the Centre Section Plane. At the tail end there is the Tail Plane, to which are attached the Elevators. And on the top of the fuselage at the tail end is the Fin, to which is attached the Rudder.

CHAPTER XXIV.

FINAL CHECKING.

Before proceeding with the fitting up of the control cables and other work, we must accurately test the leading edges of the wings to see that they are correctly in line, and also that they are at right angles to the centre line of the fuselage, otherwise the flying of the machine will be affected; also the tail plane, fin, and rudder must be checked.

We will proceed first to check the leading edge of the Lower Main Planes, because it is more convenient to do so than to get up to the leading edge of the Top Main Planes.

For the purpose of ascertaining that the leading edges of the Lower Planes are accurately in line with each other we will suspend three plumb-bobs from each leading edge. Then we will strain a line across all the six plumb-lines, starting from the left plumb-line and finishing at the extreme right-hand plumb-line.

It follows that, if the left-hand plumb-line is suspended from the tip of the left-hand lower plane, and if there are on this plane one plumb-line in the middle and one close up to the fuselage, and if there are a

similar lot suspended from the right-hand lower plane, and if a line is stretched across all of them, starting from the left and ending at the extreme right-hand one, and if the whole of the leading edge is straight, the line which is strained across will lightly touch all these plumb-lines and thereby prove that the planes have their leading edges in a continuous straight line. This is most important.

SQUARING THE PLANES.

So far we have only proved that the leading edges are in a continuous straight line. What we now have to do is to prove accurately that this straight line is dead at right angles to the centre line through the axis of the engine and fuselage.

We must therefore drop a plumb-line from the exact centre of the air-screw boss and drop another plumb-line accurately true with the centre of the rudder post. Then we must get two trestles or some objects having sufficient weight in themselves to allow a line to be tied to each and strained taut. This line must reach from the plumb-line of the screw boss to the line suspended from the rudder post. As this line reaches from end to end of the machine, it naturally will cut the line representing the leading edge of the lower main planes.

Having got these lines set out and cut-

ting each other, the next thing to do is to find out if the line along the leading edge of the planes is at right angles to the line from end to end of the machine. This will be done with a large set-square.

CHECKING THE UPPER PLANES.

Having done this necessary checking, and having found that the Lower Planes are correct, we can start to check the Upper Main Planes. In checking the Upper Main Planes to see if their leading edge is parallel with the Lower Main Planes we must bear in mind that the Upper Planes have a forward stagger of six inches. Therefore, when the plumb-line is dropped down over the edge of the Upper Main Plane near the root of the wing, namely, at the inner end where it joins the Centre Section Plane, we shall find that the plumb-line, if the wings are correct, is six inches in front of the leading edge of the Lower Main Plane.

WHERE CARELESSNESS IS DISCOVERED.

This is as required; that is to say, if the wings are correct. We will hope they are, because, otherwise, it will entail some expensive alterations, not in material, but in the time taken, to say nothing of the annoyance. It is at this point that inaccurate work and measurements tell, and those

who have scamped their work are found out, as the accuracy of the erected wings is vital to the machine.

It will be as well to leave the two lines strained taut, namely, the line representing the centre line of the fuselage and engine, and the line representing the leading edges, as from these lines we can check the squareness and truth of the tail plane, which will next have to be dealt with.

In checking the tail plane we can do this two ways; we can measure with a steel tape from a marked and fixed point near the tip of the tail plane on the leading edge, each side of the machine, to a fixed point on the leading edge of each of the lower main planes. (Take care to use the brass ring of the tape, and include it as part of the measure, a point many men fail to note, and are consequently astounded at the imaginary error they find in the measurement, due to their own lack of knowledge in measuring with steel tapes.)

This distance should be equal on either side of the machine. If it is not, then some adjustment must be made with the fittings of the tail plane, to enable the measurements to be corrected and equal.

These measurements will have to be taken again as soon as the necessary adjustments are made and the distances equalled and corrected.

TRUEING THE RUDDER.

Whilst all this is being done, we must ascertain that the rudder is in a truly vertical position. It is hardly necessary to point out that before checking the rudder to ascertain if it is in a vertical position it will be necessary to satisfy oneself that the fuselage has not been moved or shifted from its horizontal position, both longitudinally and transversely, otherwise the check will be of no use.

To check the rudder we may use a plumb-line and plumb-bob, which can be held close up to the trailing end of the rudder, and then the inspector, or erector, can sight across this line to the edge of the rudder. If the rudder is out of truth then the edge of the rudder will not coincide with the plumb-line. This is not probable unless some bad work in the fittings has passed unnoticed.

CHAPTER XXV.

ODD JOBS AND GENERAL EXAMINATION.

Having checked the position of the leading edges of all the planes on the machine, relative to their being at right-angles to the centre line of the fuselage of the machine, we can now proceed to attach the cable controls.

Other men can be detailed to lock up all the bracing wires, with the lock-nuts, and put in all split-pins, and spread the ends of same. If circular steel wire and strainers are used, then the barrels must be locked with soft iron wire, fastened round the upper portion of the fork-end and passed through the barrel of the strainer, and the end again made fast to the wiring plate or eye-end of the strainer, to prevent the barrel from turning round owing to the vibration of the wires.

ATTACHING CONTROL CABLES.

The attaching of the control cables should be only done by experienced erectors, namely, men who are thorough and conscientious in their work, and know what are the functions and uses of the ailerons, elevators and rudder.

Before putting in any of the cables, etc.,

they must be very carefully examined for faults of any kind, even though they may have been previously supposed to have been examined and passed. The responsibility must rest with the erector who puts them in.

AILERON CONTROLS.

The first cables to put in will be the aileron controls. These will be attached to the control wheel, or control pillar, which works them.

In putting in the cables excessive tautness is not desirable, as it only puts unnecessary strain on all the pins, fork and eye-ends, cable joints, cables, and the pulleys and fittings holding them, and lastly, on the bolts holding these fittings to the spars and levers. This in due course will cause excessive resistance to movements, and will possibly cause some portion to fracture or bend.

Controls must be absolutely sensitive, and the slightest movement of the control wheel or lever should correspondingly be transmitted to the ailerons. To produce this simultaneous movement there must be perfect and equal tension in the left and right-hand control cables without excessive tautness, otherwise the machine is going to be hard to control, and very fatiguing to the pilot. These faults are most undesirable, and if allowed to exist may have bad and far-reaching results.

All controls should respond to any applied force with smoothness and ease of movement right up to the extreme limits of movement possible, and any tightness or stiffness at any part of the movement should be most carefully traced from the lever, along the cables to the ailerons, elevators, or rudder, according to whichever unit is being tested, and the fault should be removed without fail.

ANGLE OF MOVEMENT.

The angle of movement, both up and down, of the ailerons and elevators must be equal, and also be equal on both sides of the machine, one with the other. This angle of movement required will be obtained from the drawings, and must be carefully measured. The inspector must satisfy himself that the maximum angle of movement called for is obtained. This remark applies equally to the ailerons, elevators, and rudder.

In fixing up the control cables it is just as well, for the first trial, to test the control of either the ailerons, the elevators, or rudder, independently, so that in the event of any stiffness of movement existing it may be quickly located and remedied.

Having fitted up the control cables independently from the ailerons, the elevators, and the rudder, they should be all coupled up together and the whole control tested,

and if found to give the maximum angles of movement required with smoothness of working, the controls may be considered complete.

TRACKING AIRSCREWS.

The airscrew can now be put onto the shaft, with its locking nut and locking washers, after which the screw should be tracked. This consists in making sure that the axis of each blade travels in precisely the same path as all the others. If it does not, then it means that the airscrew boss is not bedded correctly at right-angles to the shaft.

The work of setting this right must not be put in the hands of any except the most experienced erectors, otherwise the fault will easily be made considerably worse, or the airscrew scrapped. It is possible that the whole of the necessary alteration may be made by slackening out the bolts on the side opposite to the airscrew blade which requires bringing into the true track, and tightening up the side affected, or vice versa, according to the direction required.

The limits allowable for screw blades to be out of the true track may be assumed to be, at the most, $\frac{1}{8}$ in. Any further amount will require to receive special sanction, and should be reported to the head of the department concerned. Possibly it may be necessary to take the airscrew off the

shaft, remove the boss from the screw, and check the sinking. It is then worth while to make sure that there is no roughness or raggedness at the edges of the bolt holes, for this would be quite sufficient to be the cause of the trouble.

GENERAL EXAMINATION.

The next thing to do now is systematically to examine the whole machine and make sure that all wiring plates are in the same line as the cables attached to them, otherwise, when the flying strain comes on them, they will flatten out, or a fork-end may snap, possibly with disastrous consequences.

Also, it is necessary to see that the angle of the bend of wiring lugs commences close up at the head of the attachment bolt, and also that one of the flat faces of the bolt-head is square to the bent lug. These details, though of no particular interest possibly to the lay mind, or inexperienced erector, are quickly noticed by the inspectors or pilots. Such errors are certain to cause considerable dissatisfaction, and will have to be eliminated. For this reason only men who have had experience in erecting machines ready for flight should be put on this inspection work, as their training and past experience in these matters enables them to know exactly where to look for faults, and when found, to know

if they can pass the work or not. And if they will not pass, as they should not, they know what is the most suitable way of dealing with such faults.

The next thing to examine will be the cable-ends and strainers, or fork-ends, and see that all split-pins are properly put in. There are a considerable number of people, both men and women, whose duty at times is to put split-pins into position, who have not the remotest idea of how they should be put in, and the ghastly samples of this simple operation which are frequently met with certainly call for comment of a forcible or even lurid character.

SPLIT-PINS.

A split-pin consists of a length of half-round soft iron wire bent double, with a loop in the middle of the length, and the ends when closed together meeting evenly and forming a round wire, to all intents and purposes.

The split-pin thus described is generally used to pass through two slots of a castellated nut and the centre of the bolt, not less than 1/16 in. from the end of the bolt, the loop of the split-pin remaining outside the slot of the nut, and not forced, hammered, or punched into the slot of the nut and mutilated. The length of split-pin passing through the opposite slot should be equal in length to the diameter of the

bolt. This length is split open and the ends opened and bent back against the side of the nut.

The loop at the end of the split-pin, which should project beyond the nut, should not be damaged, as this loop is needed to catch hold of should the split-pin have to be removed at any time.

PIPE TESTING.

Having dealt with the erecting and completing of the machine, the oil and petrol tanks should be filled up, and a careful test made to see that all pipe connections are correct, and that there are no leaks of any description.

It is quite possible that one or two pipe joints may require attention. Also, petrol and oil cocks sometimes require grinding in, in which case a small tin of "grinding-in paste" will be useful, but extreme care must be taken to make sure that all traces of this paste are removed after grinding in a plug, or any valve.

TOUCHING UP.

Having completed erection, it will be necessary for the painters and polishers to come along and touch up the fittings which may have had the enamel damaged, or struts which may have become dulled, and to do any other polishing or incidental work necessary for the proper finishing off of the machine.

OVER-ALL INSPECTION.

The work on the machine having been completed, the works inspection department should be duly notified, and a couple of men sent to inspect the machine thoroughly all over, in detail. To save trouble and time, a good plan is for the inspectors to have a supply of small red "tie-on" labels, which can be tied onto any part of the machine requiring attention. They should write on the label the number and nature of the defect, so that when the erectors come to remedy any faults, the nature of the defect may at once be known to them by referring to the label.

After the defect has been remedied the label must be replaced on the previously defective or unfinished part, so that the inspector on his return can refer to his note-book and the number of the label and see that the defect has been remedied.

The use of this system enables another inspector to go through the whole machine, and this acts as a double check, as it is quite possible that some fault may be spotted which has hitherto remained hidden, and further, it causes the first inspector to be keener on his inspection, as he does not want the second man to notice defects which he himself has missed.

THE VARIOUS GADGETS.

Instruments, such as the compass, air-speed indicator, revolution indicator, inclinometer (if any) and various other "gadgets," such as gun-mountings and so forth, will have been fitted at convenient stages in the finishing of the machine. Some of them may not be fitted by the manufacturer at all, but by the purchaser—the Navy or Army, as the case may be, or in these days, the Air Force, or later on by some private customer or foreign Government. In any case, they are not produced in our factory, and have nothing to do with how we build our aeroplanes, so we need not discuss them in detail. They have to be fitted as the officials sent down by the purchasers wish them to be fitted, and we have to follow their instructions. So we fix the instruments and gadgets accordingly.

The machine may now be considered finished and ready for handing over to the aerodrome, whence it will receive its final inspection by the A.I.D. and engine tests before being flown.

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